THE
GEOLOGICAL MAGAZINE
VOLUME LXIV.

No. XI.—NOVEMBER, 1927.

ORIGINAL ARTICLES.

Contemporaneous Volcanic Activity in East Fife.

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(PLATES XIV, XV.)

IN a previous contribution to the GEOLOGICAL MAGAZINE [1] the opinion was put forward, based upon an examination of field evidence available in the neighbourhood of Largo, that the assumption of a Permian age for the old volcanoes of East Fife should no longer be sustained. It will be remembered by those interested in the matter, that whereas this district afforded remarkably clear evidence of contemporaneous volcanic action during Lower Carboniferous times, no confirmation was forthcoming of Sir A. Geikie's wholly different structural interpretation of an overlying unconformable sheet of post-Carboniferous ash. The purpose of this paper is to supplement the conclusions arrived at three years ago, and to note one or two additional field exposures that seem likewise to indicate contemporary eruptive activity among the Lower Carboniferous rocks of East Fife.

In the stream discharging into the sea west of Lower Largo, and above the great boundary fault that throws down the Barren Red Beds of the Coal Measures against the members of the Upper Limestone group, on the north, the strata are displayed in excellent section. The rocks of the latter series dip to the east and can be followed in descending order as we go up the watercourse. About ten yards below the sharp bend just south of Flour Mill Farm, a hard rib of "whin-ash", dipping east at ten degrees, underlain by shales and overlain by yellow sandstones, some of which are ripple-marked and flaggy, crosses the stream. The ash is about 9 in. thick and consists mainly of sandy material, but includes also fragments of coal and various broken up sediments, as well as numerous lapilli and irregular pieces of white-trap. This deposit is associated in intimate fashion with the accompanying strata, its mode of occurrence affording a sure proof of contemporaneity. The horizon of the igneous material is uncertain: some coal seams cross the stream not far to the east and it is possible that these are lying just below the Index Limestone. If that surmise be correct, then the "whin-ash" would be fixed in position as occurring on a lower level than the main Largo volcanics, and corresponding stratigraphically probably to the bedded ashes exposed on the shore north-west of Chapel Ness at Elie. It may be mentioned that a few feet below the ash-bed noted another of similar kind is meantime visible (on left bank, just above stream angle).

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[1] Vol. LX, 1923, p. 530.

Reference to the published 1 inch map of H.M. Geological Survey will show that the ground under notice is mapped as occurring in the area occupied by the Red Beds of the Coal Measures. But this must be in error, for the fracture probably crosses at least 300 yards further south, passing apparently close to the railway station at Largo.

Three miles to the north-west of the above locality, and in the neighbourhood of Letham, a quantity of volcanic material has been detected by boring operations. In the Geological Survey Memoir on East Fife the occurrence of this is noted, but it is stated that in the absence of satisfactory field evidence, no precise determination of its time relations is possible. In the course of last summer there were observed by the writer such exposures as seem to throw light upon the matter. From the main road that runs past Montrave to Kennoway and Windygates, there branches off a highway that leads to Scoonie and Leven, past the old castle of Aithernie. A short distance south of this junction the Leven road will be found to bridge a railway—the mineral traffic line from Lochty, Lathallan, Gilston, and Montrave to Thornton. It is immediately below this bridge and in the cutting for a few hundred yards to the west, where another bridge, erected for the convenience of neighbouring farm tenants, crosses the rail track, that the volcanic sequence now to be noted can be seen. Just west of the second bridge, and east of it for about 40 yards, a section of bedded volcanic tuffs is exposed, dipping generally west at 20°, and abutting on their easterly extension against a mass of sandstone, in relation to which they are evidently faulted. The stratification of the ashes is well marked, the harder ribs standing out prominently on the face of the cutting. Sometimes the layers are disturbed by small faultings and flexurings and they also exhibit depositional unconformity. Besides including a large amount of dark carbonaceous matter there are enclosed abundant green decomposing lapilli of basic lava. Here and there a large ejected block of ashy sandstone or impure limestone can be detected. The sandstone, referred to as contiguous to the ashes, likewise dips to the west, is false-bedded and includes carbonaceous intercalations. East of this point finely bedded ashes, with harder bands dark and coaly-looking, but sometimes highly micaceous, dip to the west (Plate XIV): these, however, soon roll over an anticline and then dip east along the cutting. A close scrutiny of the section exposed at this point will convince the observer that what is presented to him is indubitably a contemporaneous suite of volcanic deposits, the alternations of slightly coarser detritus with more highly comminuted material bringing at once to his mind a history of intermittent eruptive activity. The calcareous nature of many of the harder ribs is noteworthy and from some of these plant fragments, showing distinct structure, have been collected. East for some distance no rocks can be seen, although one or two outcrops on the grassy banks seem to indicate that the dip is still in the same direction. About 100 yards west from the easterly bridge, a massive green ash is seen to undulate and then again to dip east. After another interval of about 80 yards, we come upon shales with plants and that include interstratified thin layers or films of volcanic dust. At the base of the south bank and just west of the bridge, a zone of volcanic rock, about 2 ft. thick and with a hard calcareous top, can be seen. This material weathers red and is exceedingly tough under the hammer. East of the bridge the volcanic sequence is lost, and micaceous shales, topped by a coal 15 in. thick and of inferior quality, dip under a thick zone of white and gritty sandstone.

The accompanying diagram (Fig. 1) will indicate the structure along the cutting: further comment is probably unnecessary. It is apparent that we are on safe ground in pronouncing the vulcanicity recorded by these deposits as belonging to the Lower Carboniferous, the country rock as ascertained and mapped by H.M. Geological Survey, and not to any later post-Carboniferous manifestation.

The next locality, where it is suggested there exists in East Fife clear evidence of contemporaneous volcanic activity, is that upon the east side of Largo Bay at Ruddons Point. This long-jutting headland, which obviously owes its existence to the igneous material of which it is composed, can be reached either by a traverse of the coast west from Earlsferry or from the railway station at Kilconquhar, from which point it is distant somewhat less than 2 miles. Having attained "Shell Bay", we note, that on the north-west side of Kincraig Hill, there emerges upon the beach a series of flaggy strata, undulating at low angles but inclining mainly across the sandy inlet towards Ruddons Point. Beyond the bay, similar strata appear, again rolling, and showing in the north-east corner a transgressive junction with igneous material, this being a volcanic vent boundary as described in the East Fife memoir.

But, before proceeding further, it may be of interest to indicate the argument in respect of which it was considered expedient to re-examine this portion of the coast. It will be remembered, that one of the conclusions formerly reached was to the effect that the structure of the Largo district was that of a large shallow syncline; and, furthermore, that the clearly interstratified ash zones which that region disclosed, were probably intercalated somewhere about the horizon of the Index Limestone. Deliberating these facts, and recollecting that the south-easterly limb of the great fold should, and did, emerge to the surface somewhere upon the north-west

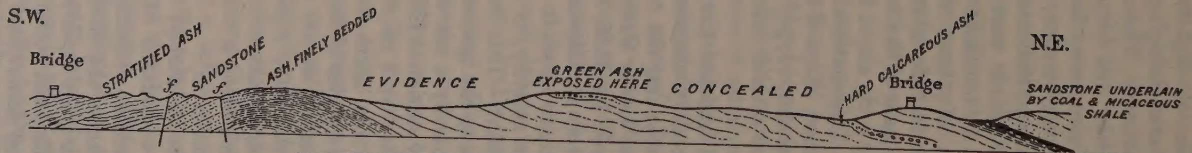

Fig 1. SECTION IN RAILWAY CUTTING NEAR LETHAM, FIFESHIRE.

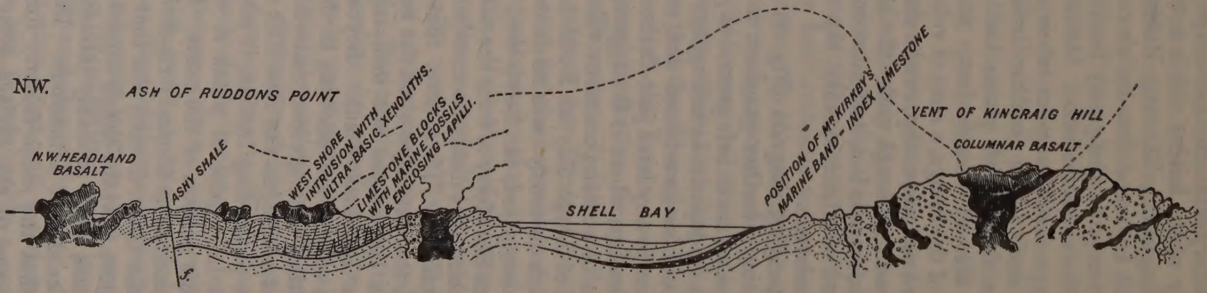
N.W.
ASH OF RUDDONS POINT
N.W. HEADLAND BASALT
ASHY SHALE
f
WEST SHORE INTRUSION WITH ULTRA-BASIC XENOLITHS.
LIMESTONE BLOCKS WITH MARINE FOSSILS & ENCLOSING LAPILLI.
SHELL BAY
POSITION OF MR KIRKBY'S MARINE BAND - INDEX LIMESTONE
VENT OF KINCRAIG HILL
COLUMNAR BASALT

Fig. 2. SECTION FROM KINCRAIG HILL TO RUDDONS POINT, FIFESHIRE.

side of Kincraig Hill, because it was here Mr. Kirkby obtained palaeontological evidence of a horizon that seemed to represent the Index Limestone, it appeared reasonable to suppose that the igneous accumulations of Ruddons Point, lying further within the fold and thus, having regard to the shallow angle of dip, occurring among sediments of a slightly higher stratigraphic level, might furnish evidence of a quality not available at any of the eastern and inland necks. For it had been supposed that the higher you ascend stratigraphically among the Lower Carboniferous rocks of East Fife, the more clearly do the included materials of their associated volcanic necks become recognizable as forming the relics of extinct volcanoes. At Ruddons Point lay a horizon higher than at Kincraig Hill, where still stands an old crater with fan-shaped display of basaltic columns. Was it not possible that interesting new evidence might here be yielded, and incidentally confirmation forthcoming of the conjecture noted above. The work was thus undertaken with a preconception that special significance might attach to the task. And what follows is based upon a series of traverses during a recent brief period of leave from official duties in the Royal Scottish Museum.

Resuming now an examination of the coast at the transgressive junction above referred to, the observer will have no difficulty in convincing himself that he is here dealing with a neck margin. A basalt dyke, or dykes, in association with coarse breccia, can be seen bounded on the south by sedimentary rocks, and on the north by well-bedded ashes, the layers of which are turned down against the intrusive material. This turning down of the ash layers seems quite comparable to the inflexion of the sandstones outside the south boundary, and it is obvious we are here concerned with a narrow blow-fissure or vent-orifice, up which the basalt has risen, either maintaining its massive character or breaking up into blocks. A few yards across this dyke-like injection, the ash layers roll over and dip to the north and north-east. An arresting feature may be noticed at this part. Among the ashes dipping into the basalt a remarkably regular layer, or layers, of grey, sandy looking but really calcareous rock appears, simulating an ordinary sediment. This appearance, however, is entirely deceptive. The rock seems to be a deposit of calc sinter, and was probably laid down in some old pool lying at the surface during the volcanic period. Evidence of such conclusion is remarkably clear, for the rock is traversed along its stratification by beautifully even layers of basic lapilli and minute fragments of lava, that have fallen into and been buried in calcareous mud. As will be seen from the micro-photograph (Pl. XV, Fig. 3), each fragment, upon descent, has functioned as the nucleus on which an enveloping pellicle of crystalline calcite has been deposited.

Westwards the basalt dyke extends for about 100 yards, when it broadens and occupies, for about twice that distance, the upper part of the beach, beyond which the bedded ashes first referred to reappear. The later date of the basalt in reference to the ashes is here admirably shown. The dip of the tuffs now changes to north-west, and in a few yards they are again associated with a compact black basalt. At this point red clays emerge on the shore and extend west for about 200 yards, where another mass of basalt (? old lava stream having interstices filled with sand that encloses lapilli) forms a low stack on the beach. There seems little doubt that these red clays are underlying coarser ashes and tuff, as, by means of a pick, several sections were laid bare, which seemed to indicate quite clearly such a relationship. But this part of the coast is greatly obscured by seaweed. South-west from the point now reached, the transgressive south boundary of the igneous material can be followed readily across the beach. But never is there any satisfactory passage from the sedimentary rocks. With remarkable constancy the basalt seems to form the margin and to be succeeded on the north side by regularly bedded ashes. Towards low water the basalt expands into a large mass, measuring probably 100 yards in diameter, and is followed, at the extreme limit of ebb tide, by another finely columnar basalt whose columns are lying at a low inclination to the horizontal and dipping towards the land.

North and north-west of the above junction we enter upon a great beach platform of bedded ashes which on the west side of the headland dip under the waters of Largo Bay (Pl. XIV, Fig. 1) and at the upper part of the foreshore can be seen beautifully folded and traversed by basaltic intrusions. The bedding of these ashes is something quite different from what can be discerned at any of the eastern or inland necks, and confirmation is not wanting that we are justified in so asserting, when we discern amidst the ashes a layer of parrot coal, evidently the remains of old drift vegetation, sharply folded into a synclinal trough. But, if there be any doubt as to the significance of what can here be seen, let the observer confine his attention to the line of high water. A short distance north of where the coastline sweeps distinctly round to north-west (due south-west of the flagstaff on the headland), a sheet-like basaltic intrusion, called below "west shore intrusion", will be seen, lying in a syncline of finely-bedded and shaly ashes. Northward these ashes roll over an anticline, thereafter changing their direction of dip more than once. Some of the fragmentary materials displayed at this part, by their inclusion of much clastic mica and shaly intercalations that yield the remains of plants, convey unmistakable evidence of sedimentary origin. Their assortment and structural disposition point equally to contemporaneous accumulation. But the sequence of events recorded at Ruddons Point is indeed not capable of simple interpretation. First, probably, took place the accumulation of the bedded ash platform, next its injection by dykes and sheets of basalt, with accompanying differential subsidence, and lastly the development of subsequent faults and fractures.

The geological age of the platform one is inclined to fix as perhaps post-dating the Calmy or Gair Limestone, which is a slightly higher horizon than that upon which the Largo volcanics were considered to be reposing. A reason for that opinion is provided by the occurrence on the beach, a short distance south of the west shore intrusion and near high water mark, of a series of limestone blocks crowded with marine fossils, and which are thought to have been derived from the next limestone above the Index, viz. the Calmy. These blocks are of rather unusual interest, for careful examination shows that they contain the included fragments and lapilli of basic lava. One block that was sectioned showed angular fragments of felspathic basalt enclosed in the calcareous rock, pointing to some contemporaneous discharge at the period of accumulation of the ooze which now is found in the form of limestone.

Speculating further upon the history of the tuffs and basalts at Ruddons Point, proximity to Kincraig Hill is a powerfully suggestive feature. The highest parts of that one time volcano have been swept away by prolonged decay. But the cone must formerly have been one of great size. Does it not seem likely that what can now be discerned at Ruddons Point, distant by only half a mile, is a remnant of the flank of that old vent? That, at all events, is the interpretation arrived at by the writer, and such supposition finds expression in the diagram, Fig. 2.

In reference to the petrography of the basalts seen at Ruddons Point probably a great deal need not be written. It may suffice to state that they resemble closely types that have already become familiar from study at other localities in the East of Fife. The columnar rock, noted as occurring at the extreme limit of low water, is a very fresh glassy basalt that encloses abundant idiomorphic pyroxenes, and laths of labradorite felspar. The pyroxenes often show twinning on the orthopinacoid and hour glass structure. Frequently they assume the bright green tint of chromiferous diopside and then show a curious interference colour, but apparently less dispersion of the bisectrices than the titaniferous pyroxene that not uncommonly edges such green crystals. The glass of the rock is bright brown, full of magnetite, and crowded with dark polyzoiform incipient crystal growths. Olivine of first generation is represented only by pseudomorphs, but polysomatic aggregates of relatively large pyroxenes are not rare.

The flagstaff-hill basalt is merely one of several upstanding parts of an intrusion that extends to the north-west headland protruding through sand and turf. Against these, really buried stacks, the waves must have beat, when the land stood 25 ft. lower than to-day. The rock is characteristically columnar: microscopically it is a fresh glassy basalt similar to the above.

The west shore intrusion, as far as this has been examined in thin section, seems much less glassy than the other masses, but on the other hand a good deal of analcite is visible. The rock contains many sharply contoured porphyritic olivines and pyroxenes, an abundant second generation of the latter mineral, labradorite felspar, and the usual accessories magnetite and apatite. An interesting feature is the distinct tendency exhibited to non-uniform distribution of the constituents upon a microscopic scale. Thus there are small areas in each slide which in their nature afford an agreement with monchiquite, the remainder of the rock being felspathic and showing barely, or not at all, the presence of analcite. This tendency, however, has been noted at Ruddons Point to be more especially observable in some of the ejected blocks that occur in the ash. Occasionally these sectioned and examined with a magnification of, say, 20 diameters, show, under crossed nicols, a mottled appearance, the dark patches being those rich in analcite. Such ejected blocks are of a petrographic type unlike any other known to the writer in the East of Fife, but seem to be closely paralleled by an intrusive mass exposed at Seacliff Quarry, 4 miles to the east of North Berwick, on the East Lothian coast, which shows an identical uneven distribution of its ingredients. In hand specimen this latter rock has a curious glistening appearance, similar to that seen in the basalt of Kidlaw, described by Mr. E. B. Bailey,[1] where the shining faces are believed to correspond with the fracture planes of crystalline polyhedra of analcite. The basalt of the west shore intrusion at Ruddons Point shows also, it may be added, many polysomatic chondrules of olivine and pyroxene.

But the feature for which the west shore intrusion deserves special mention is its splendid showing of basic and ultra-basic xenolithic segregations. These occur in various sizes from mere nut-like pieces to nodules that measure a foot across. Their distribution seems to follow no particular rule, and they occur as plentifully in the upper portions of the intrusion as in the lower. Microscopically a noteworthy point is the remarkably fresh character of many of them. Sometimes the olivine is quite pellucid and clear, and wholly without serpentine. But this perhaps is exceptional, for in very many cases the crystals are serpentinized, either along the junction line of adjacent individuals or along cracks. Often too the mineral is traversed by dense black irregular lines, which resolve under high power into innumerable granules of magnetite lying in green serpentine. The segregations fall into various types. Thus one consists of an association of brown chrome-spinel, green, or almost colourless, chrome-diopside, olivine, and magnetite (Pl. XV, Fig. 4); another of pure olivine (Pl. XV, Fig. 1); still another of pyroxene, faintly brown, or of the purple titaniferous variety, that encloses olivine poikilitically, such nodules then affording sections that recall the typical Carboniferous picrites. Some of the segregations of olivine, and diopside, enclose sporadic patches of twinned felspar,

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[1] "The Geology of East Lothian": *Mem. Geol. Surv. Scot.*

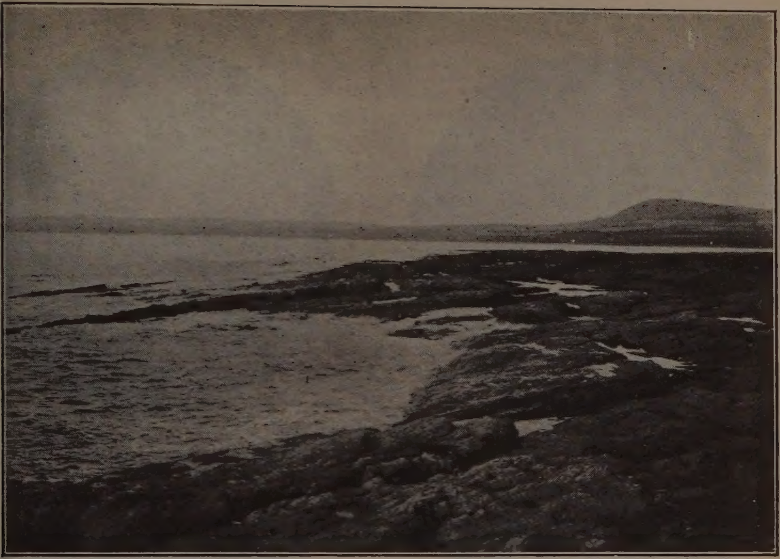

Fig. 1.—Bedded Ash Platform at Ruddons Point, Fifeshire. View looking North across Largo Bay.

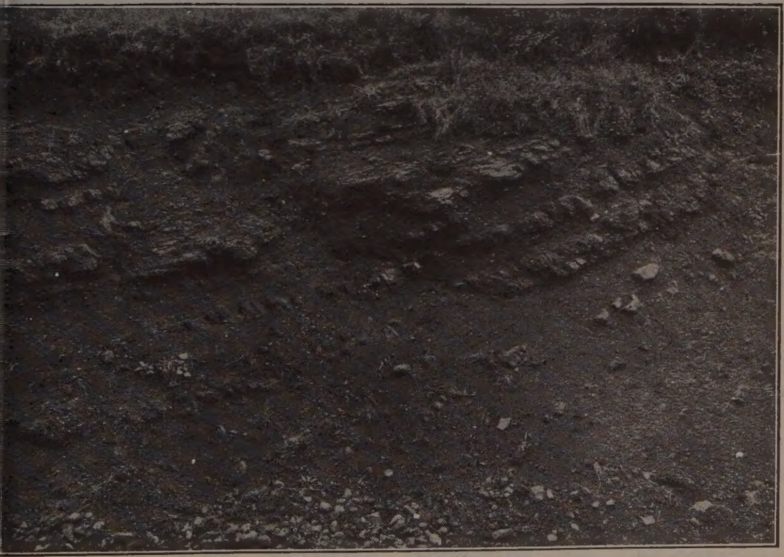

Fig. 2.—Bedded Volcanic Ashes in Railway Cutting near Letham, Fifeshire.

[*To face p. 488.*

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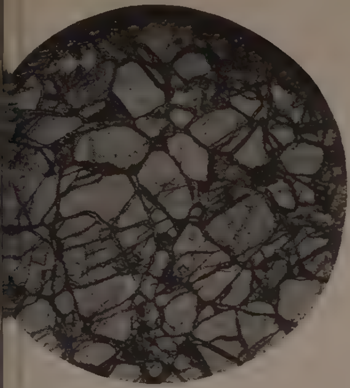

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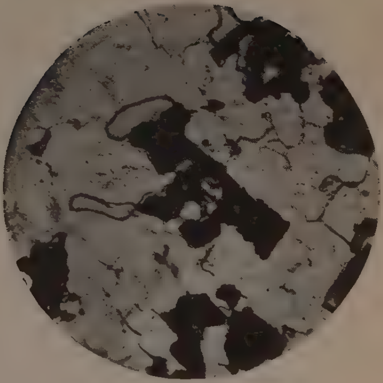

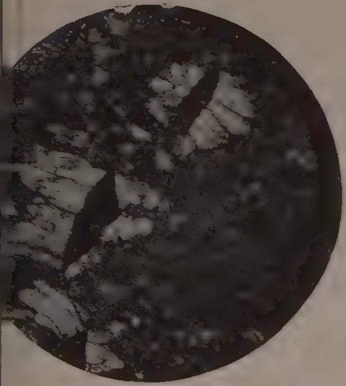

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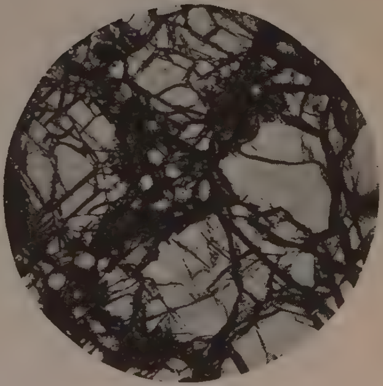

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1.—Ultra-Basic Xenolith consisting only of Olivine, West Shore Intrusion, Ruddons Point. × 30.

2.—Biotite Syenite—showing Anorthoclase Felspar, Biotite and large Grains of Calcite; Block Enclosed in Vent Agglomerate, Elie Ness, Fifeshire. × 30.

3.—Calc-Sinter, enclosing Basic Lapilli, each with Envelope of Crystalline Calcite, Ruddons Point. × 15.

4.—Ultra Basic Xenolith consisting of Chromiferous Diopside (Left) and Olivine (Right), West Shore Intrusion, Ruddons Point. × 30.

felspar, biotite, and hornblende lying between the larger felspar individuals. It is not intended here to enter into any long mineralogical account of these curious masses, but the following notes may be of interest. The hornblende, which is twinned on the orthopinacoid, has a tendency to occur with idiomorphic contours and is strongly pleochroic in shades of yellow, brown, and green: X pale yellowish-green; Y dark brown, with green tinge; Z dark green, with brown tinge; $Z{:}c$ 20–24°. Like the other minerals, however, it is also observed in rounded or elliptical granules, showing magmatic re-solution. The biotite is intensely absorbing so that sections placed with cleavage parallel to the vibration plane of the polarizer are almost black or opaque. Only in a very few sections is it possible to observe the interference figure, when it can be noted that the mineral is biaxial with narrow angle. The zircon, which occurs plentifully, is found in corroded granules or irregular branching growths the separate parts of which are in parallel orientation. Sometimes a granule of zircon can be seen centred with a grain of calcite. This last-mentioned constituent is, too, and more generally, determined in grains either abutting against ferromagnesian minerals or enclosed in felspar (Pl. XV, Fig. 2). Its mode of occurrence suggests that in the ordinarily accepted sense it is of primary origin (such statement implying a reservation of opinion as to what, in reference to a rock magma, is really meant by the expression "primary origin"). Apatite occurs in translucent crystals, frequently of considerable size. A feature that strikes one about these rocks is that it is quite impossible to define any order of crystallization that will obtain consistently even for different parts of the same section. The felspar, carefully examined, is found to be of small axial angle, negative in character and to have its indices of refraction less than canada balsam. The crystals often show the very fine striae of albite twinning and a microcline cross hatching is not uncommon. The extinction in the girdle of faces normal to the second pinacoid is from five to seven degrees. A portion of the felspar extracted and immersed in benzonitrile, of refractive index 1·528, confirms its identity as anorthoclase, or soda-microcline. It will thus be seen that these ejected blocks are entitled to be regarded as consisting of alkali-syenite and furthermore to be of a biotite-bearing type not hitherto described as occurring in this country. In general petrographic character it is surprising in how many points they resemble the syenites described by Messrs. Adams and Barlow from the Haliburton and Bancroft areas of the Province of Ontario.[1] Apart from its occurrence as loose separate blocks in the agglomerates, the syenite is occasionally found as enclosures in the basaltic intrusions. One of these recently found by Mr. Geo. A. Cumming, of the Geological Department, University College,

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[1] Canada, Dept. of Mines, *Geol. Surv. Mems.*, Nos. 6 and 57: "Geology of the Haliburton and Bancroft Areas of the Province of Ontario," p. 227, and "Corundum, Its Occurrence, Distribution, Exploitation, and Uses", 57.

Dundee, in a basalt at the eastern margin of Elie Ness neck, was found in no respect to differ from what has just been detailed.

It may be observed that Mrs. I. F. Wallace, in her paper on the petrology of the intrusions between Largo and St. Monans, although making only the briefest reference to Ruddons Point, nevertheless notes, from other necks, nodules which consist of anhedral plates of oligoclase-andesine felspar, and that enclose brown hornblende and euhedral plates of biotite. It is probable that such nodules represent a magmatic fraction intermediate in character between the alkalic and basic facies noted above.

The precise determination of the syenite blocks has helped to clear up a matter that has long been somewhat troublesome to understand, namely the origin of the soda-microcline xenocrysts of the East Fife volcanic ashes. There can be but little doubt that they have originated from some pegmatitic modification of the syenitic magmatic fraction, as above described. Mineralogically the felspar of the xenocrysts is identical with that of the syenite. We may suppose that during long periods of quiescence, when, at any one pipe, a vertical column of liquid rock was in process of very gradual heat loss, the conditions would be eminently favourable to extreme differentiation. This having been effected, it seems likely, that upon the next accession of thermal energy, with contingent explosive phase, the products would be in part engulfed, perhaps in part assimilated, and almost certainly in large part blown out, ultimately coming to repose in the places where now they are found.

So too another, and much less well-known, ingredient of the ashes finds its origin similarly explained, viz. zircon. Crystals of this substance were first noted by one Traill, who reported the matter to Professor Heddle, but they were not found in person by the famous Scottish mineralogist. These xenocrystic zircons were not referred to by Sir A. Geikie, and they have also been ignored by subsequent writers on East Fife volcanic geology. But their authenticity is beyond question, for recently Mr. Cumming was fortunate enough to recover from the ash of Elie Ness two excellent pieces, each about a quarter of an inch in length, and one slightly larger fragment loose on the beach. When these were submitted to the Royal Scottish Museum, for confirmation of their identity, I had no difficulty in ascertaining their refractive index to lie above that of a liquid of index 1·83, but below that of a sulphur-selenium melt, of accurately determined index 2·2. Also their optically uniaxial, positive, character could be easily verified, likewise their containing zirconium, by blowpiping in a fused bead of potassium fluoride and thereafter testing with turmeric. That Mr. Cumming's crystals are zircon there is thus no reason to doubt. One of the fragments collected in situ showed a combination of tetragonal prisms and pyramids; the other was pitted on the outside with minute thumb marks.

Returning now to the main theme from which the above paragraphs have digressed, it may in conclusion be recapitulated that the essential purpose of these notes is to explain that the necessary assumption of a Permian age for the volcanic vents of East Fife should no longer be regarded as valid. The Largo district, formerly described, and sections noted above alike discover evidence subversive of such a conclusion. Largo Law and Ruddons Point, cited by Sir Archibald Geikie as affording examples of supposed Permian necks, do not survive the test of careful scrutiny in the field. It has never been intended to ignore the geological significance either of the neck exposed on the shore at Lundin Links, or that referred to in the Memoir as occurring at Kennoway Den. But considerable difficulty is experienced in assimilating any general assertion of a Permian age allocation based only upon petrographic argument.

Dr. G. W. Tyrrell, writing in reference to my former paper,[1] expresses regret that the idea of a Lower Carboniferous age for the necks of East Fife has been countenanced on the basis of evidence obtained from one of the least typical of them. His reference is of course to Largo Law, where examination of the surrounding country so clearly revealed a series of interstratified tuffs. Yet this vent was regarded by Sir A. Geikie in some of his latest specific writings as belonging to the Permian suite, and indeed a shaving a critical bearing upon the age problem. Dr. Tyrrell further writes that it is the small green-hill type of neck which appears to be characteristic of late-Carboniferous and Permian vulcanicity. But such averment can scarcely be regarded as serious argument. He suggests a comparison of Largo Law with the Heads of Ayr vent, where it is thought that although the pyroclastic filling of that orifice may be of early date, yet the basaltic intrusions are much later in time: the same vent having probably been utilized during the recrudescence of late Carboniferous activity. It is difficult to imagine, if that opinion be correct, how the contents of the neck escaped evisceration during the second instalment of its volcanic history. Dr. Tyrrell seems unable to accept the view that analcite basalts, monchiquites, and teschenites were produced in early Carboniferous times.[2] But as long as he persists in adhering to that conviction just so long, one is driven to think, must his progress be grievously impeded in an understanding of Scottish Carboniferous igneous geology.

Mr. Bailey, it is agreeable to note, now concedes the occurrence in East Fife of vents of Lower Carboniferous age.[3] But he falls probably into error in presuming that all those necks whose agglomerates yield quartz-dolerite fragments must necessarily be Permian, and certainly into serious error in asserting that I have correlated such disrupted blocks with the quartz-hypersthene diabases of Southern Forfarshire.[1] The purpose of citing these last-mentioned masses was solely to emphasize the point that rocks of like petrographic character have had their genesis at quite different periods in geological time; and that although quartz-dolerites are found cutting the Coal Measures, that fact did not of itself constitute any sound reason against inferring that some of the intrusions of similar type, now found among Lower Carboniferous rocks, were emplaced there in Lower Carboniferous time. It was from such masses that the ejected blocks of the East Fife necks were thought to have come, not from the deep underlying Old Red Sandstone as apparently misunderstood by Mr. Bailey. With Mr. Bailey's conclusion that the rocks of the quartz-dolerite suite of the Forth and Clyde area are of Permo-Carboniferous age it does not seem possible to agree. Rather perhaps should they be regarded as Mr. Bailey does the teschenites, viz. of various dates corresponding with volcanic episodes in the Carboniferous and Permian. But, indeed, Mr. Bailey must lately have come to see that his attempt to separate the teschenites and quartz dolerites by any wide time interval is little supported in the field. For in the *Summary of Progress of the Geological Survey*, 1925, in a reference to the teschenite-quartz dolerite complex near Cumnock, in Ayrshire, he writes that the rock of the latter type "is of approximately the same date as a biotite-rich olivine dolerite of distinctly teschenitic facies".

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[1] Geol. Mag., Vol. LXI, 1924, p. 142.

[2] Geol. Mag., Vol. LX, 1923, p. 249.

[3] "The Geology of the Glasgow District": *Mem. Geol. Surv. Scot.*, Revised Edition, 1925, p. 151.

The recognition of contemporaneous volcanic vents in East Fife at or about the period of the Upper Limestone group of the Carboniferous Limestone Series seems to bring the province into view as constituting part of a widespread volcanic field then existing in East Central Scotland. From as far west as Linlithgow, and Saline, near Dunfermline, to Aithernie evidences of paene-Index Limestone eruptive activity have long been known. And it is ostensibly also to this chapter of Carboniferous igneous history that the interstratified pyroclastic deposits of the Largo district and Ruddons Point belong. Clearly all these intercalated tuffs must have been discharged from coevally erupting orifices; and such, it is thought, in the area under discussion, can be recognized in the series of necks cutting lower stratigraphic horizons. The recrudescence of volcanic activity after the accumulation of the Coal Measures took place mainly in the counties of Ayrshire and Dumfriesshire, though apparently there were sporadic outbreaks far to the north and east of the main focus (e.g. vent on shore at Lundin Mill).

That at least is the chronologic view of the East Fife necks now attained. But let it not be thought that any claim is made to have cleared all obscurities away. Much remains to be accomplished and to future investigation the field is open and surely inviting. For, as has been eloquently explained elsewhere, probably in no other region of the world has the inner structure of volcanoes been revealed with such clearness, as it has been dissected out here by the waves of the North Sea.

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[1] Ibid., p. 151.

Lastly, if confession be permissible, the writer may state that his main interest in the igneous geology of the district in which these researches have lain has not so much been sustained by a wish to elucidate scientific technicalities, as by the fascination of trying to interpret the memorials of bygone romantic happenings that seemed for all time lost. Wandering over the bedded ash piles and rugged black basalts at Ruddons Point what a vivid impression is conveyed of the ancient volcanic terrane of East Fife. To the north, across the waters of the famous bay, rises the bicuspid summit of Largo Law, the eye naturally following the declivity by Lahill Craig, esteemed by Sir A. Geikie to be an old lava stream and ranging east to the trap-fronted height above Charleton. From still farther east looms the sombre dome of Kellie, while hard behind stands the great vent of Kincraig with its terraced western front. Thus environed the mind runs out into facile communion with the past. The far away fields and pastures seem to disappear and a vista takes shape of cone after cone diminishing in the distance, sterile and grey. Not each of the volcanic hills shows a plume of vapour blowing aside in the wind. Some are apparently in ruin and indeed on all hands we perceive the demolitions and intrenchments of the weather. Here and there may be detected the white and yellow and red of fumarolic incrustation or the products of long oxidation. The grey sand is moving in ever-changing squalls over the desolate intervening plain. Would that we might linger and explore such a territory! What promise of instruction! But the vision fades and dies, or is perhaps refigured in a new order. Now perchance appears an archipelago of volcanic islands; maybe an open woodland, dotted with pyramidal ash hills; or once more a dreary waste of basaltic gravel and sand.

It is such fragments of old history that here come drifting to us across the abyss of time. And immersed in contemplation, as we pursue the journey to Kilconquhar, over the bare links strewn with the bones of sea birds, with what force is borne in upon us the conviction that the present is superposed upon the wreckage of the past; that the existing configuration of things can be in no wise stable, but, in course, too must pass utterly away.

The Deposition of the Later Silurian Rocks of the English Lake District.

By Professor J. E. Marr, Sc.D., F.R.S.

In the *Quarterly Journal of the Geological Society* for 1925 (*Q.J.G.S.*, vol. lxxxi, p. 113) I discussed the conditions of deposition of the Stockdale Shales of Valentian age. I had intended to make a detailed study of the deposits of later Silurian age, but circumstances have prevented this. I propose to offer a few notes on the subject which may be of use to other observers.

Before discussing the deposits seriatim I would make some general remarks upon the sediments which are of Wenlock and Ludlow ages.

The Valentian rocks appear to have been deposited under fairly open water conditions, especially those of earlier date (the Skelgill Beds). The fine dark mudstones of these beds are later replaced by dominant green shales, succeeded in places by red shales, and above these again green shales, all these belonging to the Upper Valentian (Browgill) stage.

In Wenlock times the conditions favouring the formation of dark graptolite shales recurred and in Ludlow times the dominant beds were grits and gritty flags and shales.

Apart from minor changes to be noted subsequently, conditions indicate on the whole a shallowing of the later Silurian sea, but not necessarily as the result of emergence or an approach to emergence by earth movement. The whole phenomenon may be accounted for by subsidence alone with periods of rest or relatively slow downward movement. So far as I am aware, there is no evidence of actual emergence during the whole of the Silurian.

The Wenlock period seems to have been one of extensive open water. In Ludlow times sedimentation on the whole gained on subsidence, and this became more marked towards the end of the period, foreshadowing the important earth movements which culminated in Devonian times and extended far beyond the confines of the district.

The deposits of the later Silurian in the district are almost exclusively greywacke grits, silts, and mudstones, while calcareous matter is infrequent, only locally and occasionally forming definite beds of limestone of small thickness.

The beds of Wenlock and Ludlow age are classified as follows :—

Upper Ludlow . .	Kirkby Moor Flags.
Lower Ludlow . .	Bannisdale Slates. Coniston Grits. Coldwell Beds.
Wenlock . . .	Brathay Flags.

The characters and probable conditions of formation of these deposits may now be considered in order, beginning with the oldest.

1. *Brathay Flags* (*Wenlock*).—There appears to be a complete passage from the Browgill Beds into the Brathay Flags above, marked by alternating stripes of green beds of the Browgill type and blue-grey beds of the Brathay type. This is seen in several places, and is well displayed in the stream section of Spengill, Cautley.

The Brathay Flags on the whole are very uniform in character, and recall the graptolitic beds of the Skelgill group, with some differences. They are about 1,000 feet thick, consisting of finely laminated silty muds of a prevalent blue-grey colour, resembling more the lighter graptolitic beds of the Upper than the dark, often black ones of the Lower Skelgill series. They also contain sandy matter in a very fine state of division, being silts rather than mudstones. The arguments I have used concerning the conditions of deposition of the graptolite-bearing beds of the Skelgill series are therefore applicable to these also, but they were apparently deposited much more rapidly. This is indicated by the number of graptolite zones. In the 50–100 feet of the Skelgill Beds there are six important graptolite zones, some of which have been subdivided, while in the Sedbergh district Miss Watney and Miss Welch found in the 1,000 feet of Wenlock rocks four out of the six graptolite zones defined by Miss Elles in the Wenlock Shales of the Welsh borders.

Most of the beds contain graptolites, phyllocarida, and thin-tested cephalopoda only, with a general absence of undoubted benthonic forms, but in the lowest zone (that of *Cyrtograptus murchisoni*) there is in places a fair admixture of benthonic forms, such as corals and trilobites, suggesting that we have here a passage between the normal graptolitic and shelly types of deposit.

One noteworthy feature of the Brathay Flags is the abundance of large elliptical concretions, usually formed round a group of graptolites or cephalopods as a nucleus. I have called attention to these elsewhere as very widely spread in the Wenlock rocks, not only in Britain, but in many parts of the Continent. They indicate a certain amount of original calcareous matter in the beds containing them, but the exact cause of their abundance in the Wenlock Shales requires explanation, and their contained fossils, though difficult to extract from unweathered nodules, would no doubt repay collection, for the graptolites are in a state of high relief and in a condition favourable for study of the structure of the test. There is a considerable amount of iron pyrites in these beds, though considerably less than is found in the graptolitic deposits of the Skelgill Beds.

From evidence derived from districts outside the area it would appear that although the sediments suggest shallower-water contions than those under which the Stockdale Shales were formed, they indicate that continued submergence produced wider areal distribution of muddy sediments than in Valentian times, for we find graptolite-bearing Wenlock Shales succeeding coastal sediments of the shelly type, of Valentian age.

As in the case of the Stockdale Shales the shallow-water sediments of varied character with faunas of the shelly facies lay off the coasts bordering the south-eastern and north-western sides of a gulf in the more open waters of which the Brathay Flags were laid down.

2. *Lower Coldwell Beds* (*Lower Ludlow*).—A marked change in the lithology sets in at this horizon. From the base of the Silurian

to the top of the Wenlock grits are practically absent, but they now become a dominant feature.

The change from the Brathay Flags to the Lower Coldwell Beds is complete. I have seen no actual junction of the two and am unaware whether a passage exists. There may possibly be actual unconformity, but the junction requires study. The nature of the beds probably indicates a marked shallowing of the sea, though again possibly only due to the gain of rate of sedimentation upon depression.

The beds are only a few score feet in thickness, and consist essentially of rather fine greywacke grits. They have hitherto yielded no fossils, but almost certainly form the base of the succeeding deposits.

3. *Middle Coldwell Beds* (*Lower Ludlow*).—These beds are of no great thickness, probably about the same as the Lower Coldwell Beds. They are definitely of the shelly type, with no graptolites or dark colouring matter, such as characterizes the typical graptolitic deposits. The fossils are chiefly corals, trilobites, brachiopods, and mollusca, and here *Cardiola interrupta* first appears. The deposits when unweathered are blue-grey silts, with a considerable amount of fine sandy matter, and there is a considerable amount of carbonate of lime present. Lamination is absent, the individual beds being of considerable thickness, and two of the bedding planes, about a foot apart, indicate long pauses. One is crowded with *Phacops obtusicaudatus*, the other with mollusca, especially cephalopods. The fact that the trilobites are dismembered indicates that the surface of the deposit on which they rest was uncovered for a long period.

The beds are no doubt of fairly shallow-water origin, but the persistence of individual bedding planes, especially the two just mentioned, over a wide area indicates evenness of deposition. Miss Watney and Miss Welch suggest the probability that they are of the age of the *Monograptus vulgaris* zone.

4. *Upper Coldwell Beds* (*Lower Ludlow*).—The Middle Coldwell Beds seem to pass up into these. They are about 1,500 feet thick, consisting of laminated silts, rather like those of the basal zone of the Brathay Flags, but with less dark colouring matter and a larger proportion of fine sand to clay. The fauna is also more exclusively of the shelly type, graptolites being rare, and characteristic of the zone of *Monograptus nilssoni*. The character of the deposits suggests less shallow-water conditions than those under which the Middle Coldwell Beds were deposited.

The fossils are largely benthonic, corals, crinoids, brachiopods, lamellibranchs, and trilobites, but probably planktonic phyllocarida are not rare.

5. *Coniston Grits* (*Lower Ludlow*).—These beds have an estimated thickness of 4,000 feet. Their relations with the underlying Coldwell Beds have not been made out, but there is some evidence that

the junction is always faulted. They consist for the most part of green-grey greywacke grits of varying degrees of coarseness, not on the whole coarser than similar grits of other horizons in the district. A description of the microscopic structure of a specimen of these grits was given by J. A. Phillips (*Quart. Journ. Geol. Soc.*, vol. xxxvii, 1881, p. 9). The ordinary grits are entirely devoid of fossils, and the water in which they were deposited seems to have been unfavourable to the existence of life, probably for the same reason as was the case with the fine green beds of the Browgill group, as discussed in my paper on the *Conditions of Deposition of the Stockdale Shales*. There are, however, two other types of sediment in the Coniston Grits which are fossiliferous. The first is the dark silty thin-bedded band known as the Sheerbate Flags, occurring about the middle of the group. These indicate a return to the conditions under which deposits intermediate between the graptolitic and shelly types of sediment, such as the lowest zone of the Brathay Flags, were formed, approaching more to the normal graptolitic than to the normal shelly condition, as indicated by the dark colour of the rocks, and the fair abundance of graptolites. The exact zonal horizon of them has not yet been defined. The shelly fossils are partly benthonic, among them being *Cardiola interrupta*, but there may be some planktonic forms, e.g. some of the thin-shelled cephalopods.

The other type is an exceptionally coarse variety of the greywacke grits, which is highly fossiliferous, containing an abundant benthonic fauna of brachiopods, trilobites, etc. This is represented by the Winder Grit of Sedbergh, and the deposit described by Canon Crewdson on the east side of Windermere. The greywacke beds of the Coniston Grits almost certainly indicate shallow-water conditions, with a temporary deepening of the sea during the formation of the Sheerbate Flags.

6. *Bannisdale Slates* (*Lower Ludlow*).—These beds are estimated to have a thickness of over 5,000 feet, though this may be more than the actual thickness. The Coniston Grits pass gradually into them by alternation of beds of greywacke grits and mudstones, as is well seen in the railway cutting at Lowgill Station.

The beds consist on the whole of leaden grey deposits with frequent alternations of mud and fine gritty silt, several bands being often seen in the thickness of an inch. They are in fact "varved". This type of sediment is occasionally found on other horizons in the district, notably in part of the Skiddaw Slates, but nowhere save in these beds does it form the dominant type. The bands are often highly contorted, a twisted band occurring between two others with even stratification. This may be a contemporary phenomenon, not due to subsequent earth-movements. Beds of ordinary greywacke grits of varying thickness are often found intercalated between the normal banded deposits. Fossils are rare, though a few shelly forms are apparently scattered throughout, and there are two graptolitic bands, one near the base and the other towards the summit, but the graptolites are not abundant and the beds in which they occur are of a light colour. The conditions as a whole were not favourable to the existence of organisms.

A definite calcareous band occurs in these beds to the S.W. of the foot of Coniston Lake, at Tottlebank and elsewhere. Unfortunately I have never succeeded in finding it and the exposed parts have apparently been quarried away.

The varved beds were evidently laid down under exceptional conditions. Professor Lapworth in the course of conversation once compared them with the Flysch, and suggested deposition in a shallow sea, bordering a coastal belt of mountainous character, in which case they would be due to the gradual southward encroachment of the Caledonian land-mass. There is a difficulty, however, in accounting for the disappearance of this type of deposit during the formation of the sediments of the succeeding Kirkby Moor Flags. It is possible that the Bannisdale Slates were formed under different climatic conditions from those of the preceding and succeeding periods. Whatever were the exact conditions under which the banded beds were deposited they very strongly suggest formation during seasonal changes, one pair of laminae, consisting of mud and fine grit, having been deposited each year. The beds certainly deserve more detailed study.

They must have been formed with comparative rapidity. The Skelgill beds at their thinnest are 50 feet thick and as we have seen contain at least six graptolite zones, while the Bannisdale Slates, with a possible 5,000 feet have only two. This points to the possible deposition of the Bannisdale Slates at 300 times the rate of the thinnest development of the Skelgill Beds.

Towards the summit, the Bannisdale Slates begin to pass into the Kirkby Moor Flags and become much more fossiliferous, containing a rich fauna, including starfish. The conditions of deposition of these passage beds were probably much more akin to those of the succeeding Kirkby Moor Flags than to those of the bulk of the Bannisdale Slates.

7. *Kirkby Moor Flags* (*Upper Ludlow*).—These beds have a thickness of about 1,500 feet. They consist essentially of fine greywacke grits, often thinly bedded, giving rise to flagstones. Fossils are abundant and chiefly of benthonic forms. In places they occur so abundantly as to give rise to definite calcareous bands mainly composed of gastropods. The conditions on the whole suggest shallow water.

The sediments were probably, like those of the Bannisdale Slates, largely derived from the southerly land-mass, and the probability is that this northerly creeping land-mass reached the Lake District before the end of Silurian times, for the highest Ludlow rocks are not represented in the district. It is of course possible that they were once deposited and subsequently eroded.

CONCLUSIONS.

The whole of the Silurian deposits of Lakeland were probably laid down in the gulf represented on p. 123 of my paper on the *Conditions of Deposition of the Stockdale Shales.* The land margin of the gulf no doubt underwent numerous oscillations, as the result of variations in the relative rates of earth-movements and deposition, but on the whole the Lake District was under more open-water conditions in Valentian and Wenlock times, and shallower conditions in Ludlow times, but actual coastal conditions did not appear until Upper Ludlow times.

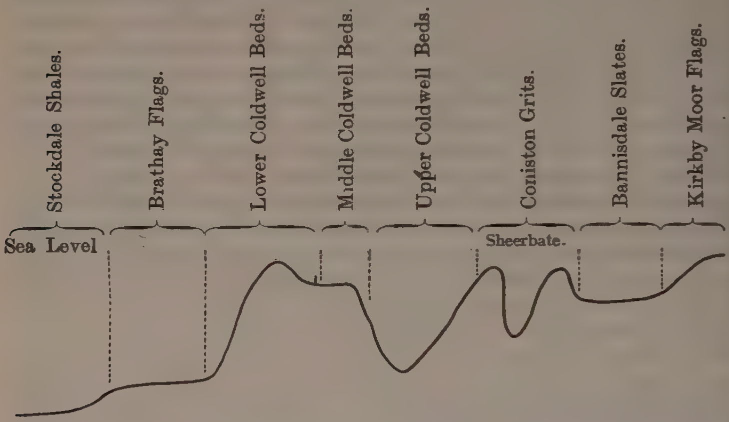

FIG. 1.—Diagram showing variations in depth of sea in the Lake District during Silurian times.

In the open water most probably about half-way between the northern and southern land-masses, the sediments were of a somewhat monotonous character, varying from mudstones through silts to greywacke grits, with little calcareous matter. During this time the coastal belts to the north and south were receiving very shallow water deposits of varied character, limestones, mudstones, silts, and grits.

Many of the changes in the character of the deposits of the Lake District were doubtless due to variations in depth and distance from the coastline, but climatic changes probably played their part. This can only be ascertained as the result of further study, and comparison with other areas. That anything approaching to glacial conditions occurred is highly improbable, judging from the nature of the faunas as a whole, and the entire absence of boulders in any of the deposits; indeed, the faunas point on the whole to fairly warm conditions having prevailed throughout the period of formation of the Silurian rocks.

Chalky Boulder-clay in the North-West District of London.

By H. G. Mantle, F.G.S., M.I.Mech.E.

At the commencement of the year 1925 the Post Office authorities, for the purpose of laying down telephone lines, were making a trench from the corner of Rochester Road (Camden Town) north-eastward up the Camden Road and across it into and along Murray Street in the direction of St. Paul's Road, and were laying ducts at the depth of about 10 ft. The distance from the corner of Rochester Road to a point opposite the corner of Murray Street is 160 yards, the direction north-east, with a slight rise in that direction. Previously the London County Council tramway cable ducts had been laid down to the depth of 3 ft. 6 in., but below this level the whole of the ground excavated was in an undisturbed state. The trench was 2 ft. 7 in. wide. A man-hole had been sunk at the corner of Rochester Road, another at the end of the works on the Camden Road, and a third opposite to it at the corner of Murray Street, all to a depth from the surface of more than 12 ft. In fact the Camden Road man-hole was sunk to the depth of 15 ft. 6 in., so as to enable the excavators to tunnel under the road to Murray Street in order that the stream of traffic along the Camden Road might not be disturbed. All along this length of 160 yards the trench showed the following section :—

	Ft.	in.
Made ground	2	6
Yellow clay	2	0
Chalky boulder-clay	6	0
Red gravel (on London Clay) . . .	2	0
	12	6

The upper part of the boulder-clay was of a brownish tint. This brown clay passed downward into a tough bluish-mottled grey clay. This contained many pieces of hard chalk (some of them rounded pebbles, others more or less angular), also many rolled and unrolled flints, some of large size, as well as pebbles of quartz, chert, quartzite, sandstone, sarsen, limestone, angular chips of shelly limestone, oolite and grit (? Carboniferous), as well as a belemnite guard. In general colour and calcareous composition the clay is identical with that of Finchley, and along the whole length a thickness of about 6 ft. was maintained.

Along Murray Street to St. Paul's Road the distance is about 310 yards, in a south-east direction, and from the man-hole on the Camden Road the workmen began gradually to reduce the depth at which the ducts were laid. At the St. Paul's Road end a deep man-hole was sunk; but the ground here is closely adjacent to a railway bridge and had evidently been previously much disturbed.

Consequently from Stratford Place (about half-way along Murray Street), where also there was a man-hole, to the St. Paul's Road end, the data may not be reliable. But from the Camden Road to Stratford Place the ground appeared never to have been previously disturbed below a depth of 6 in., which represents the thickness of the paving-flag with cement. Here, therefore, the Murray Street section would be :—

		Ft.	in.
Paving-flag			6
Mould or top soil			9
Yellow clay		2	0
Boulder-clay, very chalky .	seen to	4	0

The percentage of calcium carbonate in this boulder-clay was much greater than elsewhere, and its general appearance much more chalky. Moreover, it contained a greater number of large rolled flints, one of oblong shape measuring 7½ in. long and 5 in. wide, with a circumference of 17½ in.; also here and there a spherical flint with a circumference of 11 or 12 in. was met with. Otherwise the contained pebbles and fragments were similar to those found elsewhere.

During one of my frequent visits to these works an intelligent workman, who had been on the job all through and had previously been working for the contractors in other parts of the district, reported to me a similar occurrence of the "shepherd's plaid", as he called it, at the junction of Frederick Street with the Caledonian Road; and on 14th February, 1925, I got a remarkable confirmation of the workman's narrative from Mr. W. J. Armstrong, an official representing the contractors, Messrs. Muirhead, Macdonald Wilson & Co., Ltd., He described the section as a really beautiful one in chalky boulder-clay. They were sinking a deep man-hole, which penetrated to nearly 20 ft. Below about 3 to 4 ft. of made ground they struck a bed of yellow clay about 2 ft. thick, which was followed downward by a stiff brown to bluish chalky clay, rich in chalk, with a variety of flints and other stones, resting at about 14 ft. from the surface on a bed of water-logged red gravel, beneath which occurred the London Clay proper. This description agrees with that of the section in the Camden Road.

The distance from the corner of Rochester Road to the junction of Murray Street and St. Paul's Road is 1½ furlongs; thence to the junction of Frederick Street with the Caledonian Road is another 5 furlongs. There is no direct evidence that these tracts of boulder-clay are continuous; but, if they are, the Chalky Boulder-clay extends along a west-and-east line of 6½ furlongs.

The occurrence of what seems to be the Chalky Boulder-clay in this part of London, 3 miles south of the most southerly tract previously known (that at Finchley and Muswell Hill) appears to be worthy of record.

A Mid-Avonian Reef Limestone and Conglomerate in the Craven Lowlands.

By R. G. S. Hudson, M.Sc., F.G.S.

THE Lower Carboniferous rocks of the Craven Lowlands are predominantly fine-grained dark argillaceous limestones and calcareous mudstones and shales with a fauna of Zaphrentid or Caninoid phase. At various horizons and along various belts these argillaceous rocks are replaced by reef limestones and the associated crinoidal limestones, reef sands, and "calcaire grumeleux". These limestones usually contain a specialized reef fauna or more rarely the standard coral-brachiopod fauna.

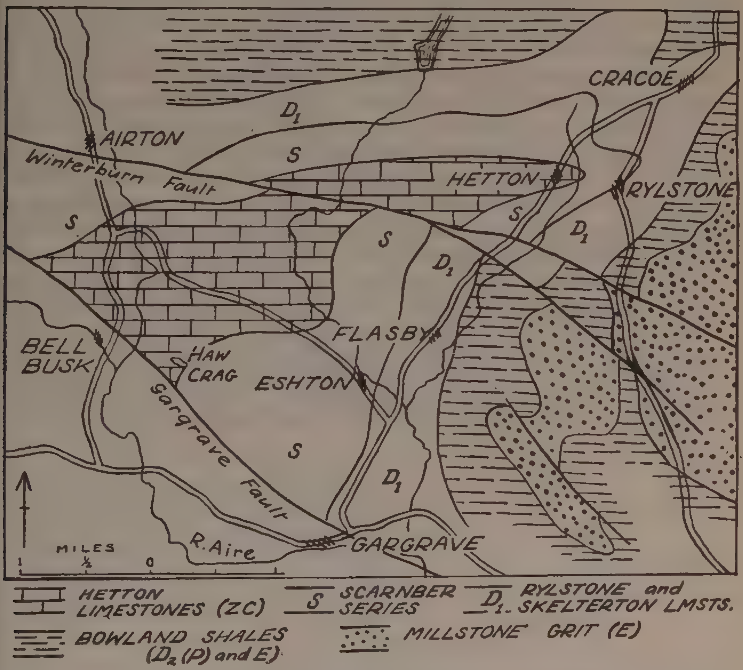

Fig. 1.—The Eshton-Hetton anticline, showing the position of the Haw Crag fault-line scarp.

The Craven Lowlands are folded into a series of E.N.E. and W.S.W. anticlines and synclines. The northern part of one of these anticlines extends from Bell Busk to near Grassington and is called the Eshton-Hetton anticline (Fig. 1). It is crossed by the faults of the Craven Fault Complex. The Gargrave Fault, one of the

South Craven Faults, crosses the south-western end of the anticline and is responsible for the formation of the fault-line scarp to the north-east of Bell Busk, a village 6 miles north-west of Skipton. The natural exposures and the quarries along and close to this scarp expose a succession of mid-Avonian limestones which are the subject of this paper. The profile of the scarp and the position of the various exposures are shown in Fig. 2. These exposures are indicated on the One-Inch Geol. Survey Map, Sheet 60 (Settle), and were described by Dr. Wilmore, (*Q.J.G.S.*, lxvi, 1910, pp. 546–8), who gave a list of the fauna of Haw Crag Quarry (Crag Laithe Quarry). In a later paper (*Proc. Yorks. Geol. Soc.*, xvii, 1911, pp. 242–5), Dr. Wilmore suggested the position of the various beds of the Eshton-Hetton anticline in the coral-brachiopod zones of Vaughan. Part of the Eshton-Hetton anticline has recently been described by Miss K. Booker and myself (*Proc. Yorks. Geol. Soc.*, xx, 1926, pp. 411–38), and it is with the sequence as described in that paper that the beds of this area are correlated. In that paper the mid-Avonian beds were described as Hetton Limestones of C age and the Scarnber Series of S age. Both these series are recognizable in the district of this paper but there occur between them beds which have not been seen in the district to the north. The lowest of these intermediate beds is the reef limestone which forms the knoll of Haw Crag. It is suggested that this limestone is of C age and is a local development of reef limestone equivalent to part of the Hetton Limestones. Above the reef limestone and separated from it by a conglomerate are limestones and shales, with a CS fauna, a fauna described by Vaughan (*Q.J.G.S.*, lxxi, 1915, pp. 17–20), and included in the Δ zone, the transition zone between the Tournaisian and the Viséan. These beds are called the Haw Crag Limestones and included in the Scarnber Series. The sequence in the neighbourhood of Haw Crag is then as follows :—

VISÉAN :

Scarnber Series . . .	Scarnber Limestone (S_2). Hetton Beck Limestones (S). Haw Crag Limestones (Δ).

TOURNAISIAN :

Hetton Limestones (C and Z) including the reef limestone of Haw Crag (C_1).

LITHOLOGICAL AND FAUNAL SEQUENCE.

Hetton Limestones.—Beds belonging to this series are exposed in the various scars and quarries north-west of Haw Crag. The best of these exposures is that of the Crags, where there is about 50 feet of limestone dipping at an angle of about 6° under the reef limestone. Well-bedded black limestones, they contain little but *Syringopora* except in a faunal band about 20 ft. from the top of

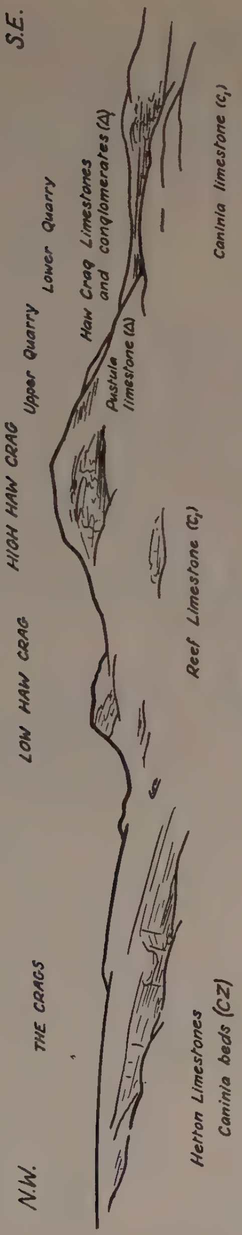

FIG. 2.—Profile of Haw Crag fault-line scarp.

the Crags, a band in which *Caninia* and *Chonetes* cf. *comoides* are common. The following fossils have been found in these beds :—

Carruthersella cf. *compacta.*
Caninia cornucopiae and variants including *C. vesicularis.*
Caninia cylindrica towards *benburbensis.*[1]
Caninia sp. early form towards *cambrensis.*[1]
Caninia sp.
Syringopora reticulata.
Syringopora sp. (fine variety).
Zaphrentis delanouei.
Zaphrentis densa.
Athyris glabristria.
Chonetes cf. *comoides.*
Chonetes aff. *papilionacea.*
Pustula sp.
Schellwienella cf. *strophomenoides.*

Reef Limestones.—The limestones exposed in the scars of Low and High Haw Crag show that the hill owes its existence to a local development of reef limestone. This limestone is light in colour, with little or no bedding and is only sparsely fossiliferous. It is shattered by vertical joints probably due to the Gargrave fault. Thin sections of the limestone show part of it is composed of a fine calcite paste with numerous foraminifera but with very little shell fragment. Pockets of dolomitic material are frequent.

About 20 feet of the reef limestone is present at Low Haw Crag, dipping 2° or 3° under the limestone of High Haw Crag. To the north-east it passes into dark, bedded, argillaceous limestone similar to the Hetton beds below, and containing a Caninoid fauna. A strike section of these beds is better seen in a line of scars to the north-east.

The reef limestone of High Haw Crag, about 50 feet thick, is higher in the sequence. The saddle between the two exposures may indicate that the limestones are separated by a softer and probably bedded limestone or that there is a small fault in between. This higher reef limestone is also exposed in the Upper Quarry.

The following fossils have been obtained from the reef limestones :—

Amplexus coralloides.
Clisiophyllum cf. *modavense.*
Clisiophyllum spp.
Koninckophyllum sp.
Michelinia cf. *megastoma.*
Productus burlingtonensis.
Pugnax cf. *sulcatus* (plicate variety).
Reticularia elliptica.
Spirifer sp. (*striatus* group).

In the Lower Quarry there are about 30 feet of *Caninia* limestones, which are apparently the equivalent of the upper reef limestone, as all gradations between the two facies can be traced. These beds contain

Caninia cylindrica mut. γ.
Caninia patula.
Caninia vesicularis.
Clisiophyllum sp.
"*Lophophyllum*" cf. *tortuosum.*
Michelinia megastoma.
Syringopora reticulata.
Syringopora gigantea.
Zaphrentis konincki (wide-angled form).
Zaphrentis densa.
Chonetes cf. *comoides.*

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[1] Kindly identified by Mr. H. P. Lewis.

Both the above faunas are of C age. The absence of *Caninia Hettonensis*, *C. cylindrica* (forma typica), and *Chonetes destinezi*—all C_2 forms found in the Hetton Limestones of Hetton—the absence of Viséan forms, the presence of *Caninia patula* and *Productus burlingtonensis*, and the abundance of *Zaphrentis konincki*, all suggest that the reef limestones are of C_1 age. The fauna of the beds below the reef limestone is not very definite. The early vesicular Caninias confirm the position of these beds below the C_1 fauna of the reef limestones and suggests a CZ age, a correlation supported by the fact that the Eshton Moor beds, the lowest beds of all, are of Z age.

Haw Crag Limestones.—The quarries on Haw Crag expose the beds which rest on the south-west flank of the reef limestone. The rapid lateral changes and the intermittent uplift and erosion which took place after the deposition of the reef limestone have complicated the succession and therefore, since the succession is clearer in the lower quarry, that will be described first. This lower quarry has been worked both along the strike—the S.E. face—and along the dip—the N.E. face. The lowest beds near the floor of the quarry are dark limestones with *Caninia*. On the strike face these beds pass upwards into the *Caninia* limestones with the fauna listed above; on the dip face a conglomerate with rounded and sub-angular boulders rests on the eroded surface of the limestone. This conglomerate is about 15 ft. thick. The boulders vary in size, though most of them are from 1 to 3 feet across; they are either of dark limestone or a lighter coloured porcellanous limestone approaching in texture to reef limestone, while shale or small pebbles fill the spaces between them. In this bed there is an isolated and vertical block of limestone 10 feet long and 12 feet thick, showing no signs of water erosion, a block apparently nearly in situ. This conglomerate is also exposed on the strike face of the quarry, but there its maximum thickness is only 3 feet, and in one place it is entirely missing as the beds which usually occur above the conglomerate rest directly on the *Caninia* limestone.

Above these lower conglomerates there is a shale which contains an important fauna. On the dip face of the quarry, it is about 4 feet thick; on the strike face, it rapidly thins and becomes unfossiliferous. The lower part of this shale contains numerous limestone pebbles and the upper part thin bands of limestone. At the north end of the dip face, that is the end nearest to the reef limestone, a dark, argillaceous and apparently dolomitic limestone rests on the lower conglomerate and this is taken as the equivalent of the shale—the intervening passage beds, however, are not exposed.

Fauna of the *Cyathophyllum* Shale.

Cyathaxonia cornu.
Cyathaxonia rushiana.
Cyathophyllum multilamellatum.
"*Lophophyllum*" *fragile.*
Michelinia grandis.
Athyris roysii.

Densiphyllum nodusum.
Endophyllum sp. cf. *E. burringtonense.*
" *Lithostrotion* " cf. *cyathophylloides.*
Reticularia lineata.
Rhipdomella michelinia.
Seminula ficoides.
Spirifer spp.

Above this shale on both strike and dip faces there is a second boulder bed about 4 to 10 feet thick, often divided by a thin shale and containing large boulders—some 5 feet across—separated mainly by contorted shale. This upper conglomerate is followed by a series of fossiliferous shales, calcareous mudstones, and earthy limestones. The most abundant fossil is a *Chonetes* sp. nov., a form similar to *Chonetes hardrensis* but smaller.

Fauna of *Chonetes* beds.

Cyathaxonia cornu.
Campophyllum caninoides.
Densiphyllum nodosum.
Densiphyllum aff. *rushianum.*
Densiphyllum sp. cf. *Zaphrentis costata.*
Zaphrentis spp.
Athyris globularis.
Leptaena analoga.
Seminula sp.
Spirifer spp.
Tylothyris laminosa.
Various small lamellibranchs and gastropods.

These beds are followed by crinoidal shales and limestones containing *Cyathaxonia rushiana*, *Zaphrentis* cf. *junctoseptata*, and various small brachiopods. The sequence in the lower quarry is, then, as follows :—

LOWER QUARRY.		UPPER QUARRY.
Crinoidal shales and limestones (6 ft.).	Δ Zone	Crinoidal limestones (7 ft.).
Chonetes beds—Earthy limestones and shales (4 ft.).		Limestones and shales (3 ft.).
Upper conglomerate (4–10 ft.).		(Erosion surface).
Cyathophyllum shales (2–4 ft.).		*Pustula* limestone (6 ft.).
Lower conglomerate (3–15 ft.).		Conglomerate (0–20 ft.).
Caninia Limestones (30 ft.)	C_1 Zone	Reef limestone (6 ft.)

Haw Crag Upper Quarry.—The lowest beds in this quarry are of reef limestone. Resting on their irregular and eroded surface is a conglomerate in which the boulders are mainly of reef limestone and are, on the whole, larger and less worn than in the lower quarry. Some of the blocks in the upper part of the conglomerate and some irregular masses on top of the conglomerate which are slightly bedded and apparently in situ are very fossiliferous. The brachiopods of this bed are mostly various species of *Pustula*, and the corals early Clisiophyllids, a fauna which resembles that described by Dr. Parkinson from the Salt Hill-Worsaw knolls (*Q.J.G.S.*, lxxii, 1926, pp. 188–249).

Fauna of the *Pustula* bed.

Pustula nodopustulosa.
Pustula pyxidiformis.
Pustula cf. *aculeata.*
Pustula cf. *pilosa.*
Pustula punctata.
Pustula mesoloba.
Reticularia lineata.
Productus sublaevis.
Productus cf. *semireticulatus.*
Pugnax sp.
Arachniophyllum simplex.
Clisiophyllum sp. (CS form).
Koninckophyllum meathopense.
Clisiophyllid, gen. nov. (Smyth, *Sci. Proc. Roy. Dub. Soc.*, xiv, pl. xxxvi, fig. 2).

These beds are best seen at the north end of the quarry. Towards the southern end of the quarry they become unfossiliferous and pass into darker limestones which, apparently, are the equivalent of the *Cyathophyllum* shale of the lower quarry. These *Pustula* limestones were evidently deposited during the period of submergence that followed on the formation of the lower conglomerate but in the period following the second uplift they were partially broken up and large blocks of the *Pustula* limestone now rest, in the upper quarry, on the lower conglomerate.

In the northern part of the quarry, there are beds which have rather an anomalous position. They consist of earthy limestones and shales followed by heavily crinoidal limestones. On the eastern side of the quarry they rest on the lower part of the conglomerate and no *Pustula* limestone occurs below them; on the western side only the lower beds are seen and they rest on broken masses of the *Pustula* limestone. On both sides of the quarry a small fault separates them from the beds to the south. As these beds are later than the *Pustula* limestone, it is suggested that they are the equivalent of the crinoidal shales and *Chonetes* beds of the lower quarry.

The fauna of these Haw Crag Limestones is definitely Viséan; the *Cyathophyllum* shale and *Pustula* Limestone is of Δ (CS) age, the one of shale faunal phase and the other of reef phase, while the *Chonetes* beds and crinoidal shales contain a fauna which suggests S_1 or they may be grouped with the beds below in the Δ zone, though separated from them by a conglomerate.

FAUNAL COMPARISON.

The Craven Lowlands are included in the Central Province (Booker and Hudson, *supra cit.*, p. 434), and both the fauna and lithology of the beds described here resemble those of the Rush-Skerries area (Smyth, *Sci. Proc. Roy. Dub. Soc.*, xiv, 1915, pp. 529–562). The Rush conglomerate is of C_2 age, the age of the lower conglomerate of Haw Crag, while the beds above the Rush conglomerate, the Carylan and Holmpatrick Limestones, have a faunal assemblage similar to that of the Haw Crag Limestones.

Comparison with the fauna of the limestones north of the Craven Faults (Garwood and Goodyear, *Q.J.G.S.*, lxxx, 1924, pp. 184–273), show that the Haw Crag Limestones are of the same age as the upper part of the *Michelinia* beds, the basement beds of the Lower Carboniferous in the Settle area. The reef limestone and the equivalent *Caninia* beds are probably of the same age as the *Athyris glabristria* beds of the North-West Province, beds deposited before the Pennine land mass was submerged.

STRUCTURAL SEQUENCE.

The succession at Haw Crag shows that the formation of the C_1 reef limestone was followed by an uplift which resulted in the denudation of both the limestone and the equivalent *Caninia* beds. This sequence of reef formation and uplift—a sequence also noticeable in the Craven Reef Belt and, to some extent, in the Clitheroe area—suggests that the reef limestone was initiated on a rising sea floor, the beginning of the uplift which eventually raised the reef above sea-level and so terminated its formation. The position of the various reefs suggest that the uplift was confined to narrow belts which eventually became the reef belts.

The uplift which separates the reef limestone from the succeeding Haw Crag Limestones of Δ age was apparently of longer duration and more marked than those which followed later reef limestones. The fauna of the boulders from the lower conglomerate is that of the underlying reef limestone and *Caninia* limestones and since it is followed by the *Cyathophyllum* shales of Δ age, no C_2 beds are present. This break in the succession is comparable with that of the Rush-Loughshinny area and links the succession of the Central Province with that of the South-Western Province, for there, too, the mid-Avonian unconformity is, in the main, of upper C age.

The submergence which followed resulted in the deposition on the lower conglomerate of the *Cyathophyllum* shales and the *Pustula* limestone. The fauna of the latter is a reef fauna similar in phase to that of the Salt Hill reefs of the Clitheroe district while that of the *Cyathophyllum* shale is a " modified limestone " fauna (*Proc. Yorks. Geol. Soc.*, xx, 1924, p. 130). If these beds are contemporaneous, then their faunal and lithological differences may be explained by the fact that submergence still maintained the difference in levels between the reef and the surrounding areas so that a fauna of *Pustula* and associated forms were able to thrive on the old reef surface—either because of the comparative shallowness of the water or else because of the freedom from the fine detrital material that was being deposited in the surrounding areas—while a shale fauna lived on the relatively deep and muddy reef slopes.

The deposition of these beds was followed by a second uplift and the formation of the upper conglomerate. The erosion following the uplift had little effect on the *Cyathophyllum* shales—most of the boulders in the upper conglomerate are of C_1 *Caninia* limestone. The *Pustula* limestone of the reef area was, however, broken up so that in places broken masses of it rest on the lower conglomerate.

Final submergence resulted in the deposition of the *Chonetes* beds—in which there are occasional pebbles—and the *Cyathaxonia* shales. These beds, too, show a difference between those deposited in the reef area and those of the surrounding areas ; the former are heavily-crinoidal limestones while the latter are shales full of loose crinoidal ossicles. The rest of the sequence is a normal one similar to that of the Skipton area, that is, the S, D, and E beds are all shales with thin black limestones of Culm facies and sparsely fossiliferous.

Haw Crag is only 5 miles south of Malham, where the Avonian rocks are of northern facies and rest on the Pennine land mass of Lower Palaeozoic rocks, a land mass which was not submerged until the beginning of the Viséan. The C_1 reef limestones, therefore, must have been deposited close to the southern shore of this land mass and might have been of the nature of a barrier reef. The Haw Crag limestones are of the same age as the *Michelinia* beds which were deposited on the southern flanks of the land mass at the beginning of its submergence. This submergence was intermittent, for the basement conglomerate of $\varDelta$ age includes fragments of limestone of earlier age (Garwood and Goodyear, *op. cit.*, p. 191), and this oscillatory movement may well be correlated with that which produced the upper conglomerate of Haw Crag.

On Some New Ammonoidea from the Chalk Rock.

By S. A. Billinghurst, B.Sc. (Lond.).

(PLATE XVI.)

I. Introduction.

As a result of work on the Chalk Rock in the Hitchin district during the last two years, I have obtained several Ammonoidea which differ in certain respects from those already figured and described and include two new species.

Since the exhaustive memoir of Mr. H. Woods on the Mollusca of the Chalk Rock,[1] very little new work has been published on the fauna of this interesting deposit. In 1904 volume iii of the Geological Survey Memoir on the Cretaceous Rocks [2] was issued. Numerous lists of fossils were given, but no new forms were recorded from the Chalk Rock. It was stated that Chalk Rock fossils were obtained from the district south and south-east of Hitchin, but it appears that the chalk pit near Hitch Wood, from which the specimens to be described in this paper were obtained, was not included in the official account. In 1909 Messrs. Chatwin and Withers added a contribution to the fauna of the Chalk Rock,[1] and in 1911 A. H. Noble recorded an additional species.[2] Between 1922 and 1926 Dr. Spath in several papers[3] revised the classification of certain forms from the Chalk Rock.

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[1] "The Mollusca of the Chalk Rock," part i : *Q.J.G.S.*, vol. lii, 1896, pp. 68–98 ; part ii : *Q.J.G.S.*, vol. liii, 1897, pp. 377–404.

[2] "The Cretaceous Rocks of Britain. Vol. III. The Upper Chalk of England, 1904" : *Mem. Geol. Surv.*

II. Occurrence.

It will be useful to indicate the location of the quarry at Hitch Wood. It is situated about 2 miles west-south-west of Stevenage Station (L.N.E.R.), on the south side of the road which leads south-westwards from the Hitchin-Welwyn road to Whitwell. The pit is marked on the 6-in. Ordnance Survey Map, Hertfordshire, Sheet XII S.W., and is shown to be north-east of Hitch Wood, about 250 yards west of Hillend Farm. The farm is marked on the

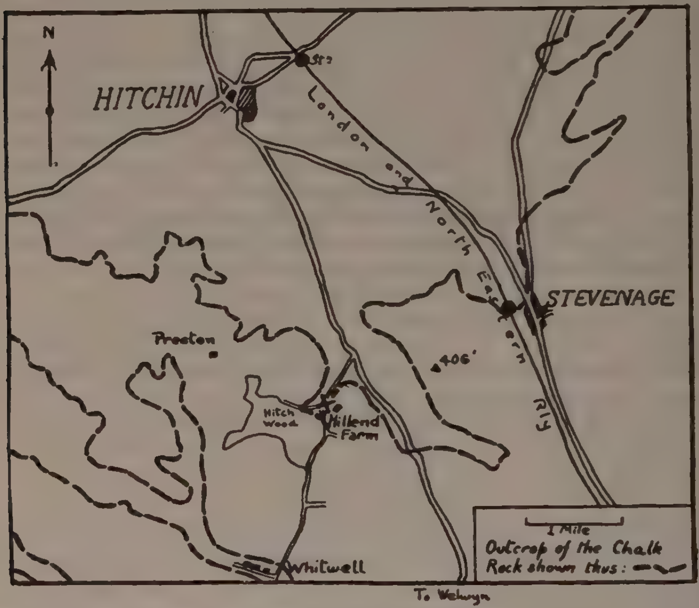

Fig. 1.—Map of the Hitchin and Stevenage district. Scale: ½ in. to the mile (or 1 : 126,720). The chalk pit is situated at the point marked X.

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[1] Geol. Mag., 1909, pp. 66–9.

[2] "On a new species of *Desmoceras* from the Chalk Rock of Buckinghamshire": Geol. Mag., 1911, pp. 398–400. Figs. 1, 2. This species has now been made the genotype of the Genus *Pseudopuzosia* Spath. See Geol. Mag., 1926, p. 80.

[3] "On New Ammonites from the English Chalk": Geol. Mag., vol. lxiii, 1926, pp. 77–83. "The Senonian Ammonite Fauna of Pondoland": *Trans. Roy. Soc. S. Afr.*, vol. x, pt. iii, 1922, p. 128. "Ammonoidea of the Gault": *Mon. Pal. Soc.*, pt. i, 1923, pp. 35–9.

Geological Survey 1-in. Map, old hand-coloured edition, No. 46 S.E. Woburn (Drift), published in 1898, but no chalk pit is indicated. The accompanying sketch-map shows the position of the chalk pit and the outcrop of the Chalk Rock.

The following section is exposed :—

	Ft.	in.
White chalk, much broken and weathered at its upper surface, with scattered flints .	12	0
Chalk Rock. Hard, cream-coloured limestone, iron-stained and much broken in places . .	2	6
White chalk . . . . seen for	10	0

Chatwin and Withers[1] place the Chalk Rock at the base of the *Holaster planus* zone. In the country between Goring and Shiplake, they found the *Terebratulina* zone immediately below the Chalk Rock.[2] Up to the present, however, the quarry at Hitch Wood has not yielded the typical zone fossils, i.e. *Holaster planus* and *Terebratulina lata*. From the white chalk in the upper part of the section, a few inches above the Chalk Rock, a specimen of *Micraster praecursor* Rowe (kindly identified by Mr. Withers) was obtained, whilst the white chalk below gave *Spondylus spinosus* J. Sowerby.

In addition to numerous specimens of the Ammonoidea listed below, *Micraster leskei* Desmoulins, *Micraster praecursor* Rowe, *Phymosoma*, *Ventriculites*, *Parasmilia*, and many Terebratulids, Rhynchonellids, and Gastropods were found in the Chalk Rock, but the faunal assemblage does not permit of the exact determination of the position of the Chalk Rock within the *Holaster planus* zone, or Dr. Spath's Upper Prionotropidan age.

The fauna obtained from the Chalk Rock may be described as fairly prolific, and most of the specimens are in a good state of preservation. The rock itself is moderately hard, and is honeycombed with numerous solution channels, which contain iron-stained clayey material and permeate the layer in all directions. These channels are absent in the white chalk above and below. Dendritic markings are common, and the crushed rock yields abundant glauconite. The Ammonoidea collected from the Chalk Rock are shown in the following list :—

Pachydiscus sharpei Spath.
Prionotropis cristatus sp. nov.
Prionocyclus hitchinensis sp. nov.
Scaphites geinitzi (d'Orbigny).
Hyphantoceras woodsi (Kitchin).
,, sp. nov. ? (*reussianum* group).
Allocrioceras ellipticum (non Mantell) Woods.
Cyrtochilus bohemicus (Fritsch and Schlönbach).

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[1] "On the Chalk Section at the Waterworks Quarry, Marlow": Geol. Mag., 1909, pp. 123–5.

[2] "The Zones of the Chalk in the Thames Valley between Goring and Shiplake": *Proc. Geol. Assoc.*, vol. xx, 1907–8, pp. 390–419.

In addition to the above Ammonoidea, several specimens of "*Nautilus*" *sublaevigatus* d'Orbigny were found.

Specimens of *Pachydiscus sharpei*, *Allocrioceras ellipticum* and *Hyphantoceras woodsi* exhibit certain characters different from those described by previous authors, and these features are accordingly dealt with and the two new species described below.

III. PALAEONTOLOGICAL DESCRIPTIONS.

Family PACHYDISCIDAE Spath, 1922.

Genus PACHYDISCUS Zittel, 1884.[1]

Pachydiscus sharpei Spath. (Text-figure 2.)

1853. *Ammonites peramplus* non Mantell, Sharpe. Description of Fossil Remains of Mollusca found in the Chalk of England. *Mon. Pal. Soc.*, p. 26, pl. x, figs. 1 and 2 only (fig. 3 = *P. cricki* Spath).

1926. *Pachydiscus sharpei* Spath. On New Ammonites from the English Chalk, GEOL. MAG., Vol. LXIII, p. 82.

Several specimens have been obtained. Large examples are rare, as noted by Messrs. Chatwin and Withers.[2] Mr. Woods[3] records a specimen of probably the same species 8 inches in diameter, which was obtained from Luton cutting. Two large specimens have been obtained from the chalk pit near Hitch Wood. One exhibits good preservation of whorls and suture lines to a diameter of 105 mm. The suture line, from a tracing, is here figured, since Sharpe's drawing is obviously sketchy, and he did not figure the internal half.

The other example is much larger, but unfortunately in a bad state of preservation. The inner whorls are complete to a diameter of 100 mm., but the outer whorls are only partially preserved. The complete specimen must have had a diameter of 200 mm. Sharpe figured two specimens, which he supposed to be an old (fig. 1*a* and *b* in his plate x) and a young individual (fig. 2*a*) respectively. The periphery of the outer whorl of the larger specimen is shown to be smooth, whilst that of the smaller is ribbed. In the second specimen from Hitch Wood mentioned above, the ribbing is well-defined and continuous across the lateral and peripheral margins of the inner whorls, but becomes fainter in the outer whorls, until at a diameter of 100 mm. the peripheral margin is quite smooth. The outer whorls then resemble Sharpe's fig. 1*a* and *b*, and the inner whorls are like those illustrated in his fig. 2*a*. The specimen is interesting in that Sharpe's two forms are now proved to belong to the same species.

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[1] For use of term *Pachydiscus* see Spath, "Ammonites from the Gingin Chalk": *Journ. Roy. Soc. West Austral.*, vol. xii, 1926, p. 55.

[2] Loc. cit., p. 66.

[3] Loc. cit., p. 80.

Family PRIONOTROPIDAE Zittel, 1884.

Genus Prionotropis Meek, 1876.

Prionotropis cristatus sp. nov. (Pl. XVI, Figs. 3*a*–*c*.)

1896. *Prionocyclus neptuni* (Geinitz) Woods, pars, loc. cit., pp. 77–8, pl. iii, fig. 3 only.

Specific Characters.—Coiling platy—subleptogyral, subangust—co sublatumbilicate. Whorl-section subquadrate, costae first close, later more distant, alternately bi- and tri-tuberculate, somewhat irregular. Highly crenulate siphonal line. Suture-line with very wide external saddle and subtrifid lateral lobe.

Measurements of Holotype.—44, ·40, ·30, ·34.

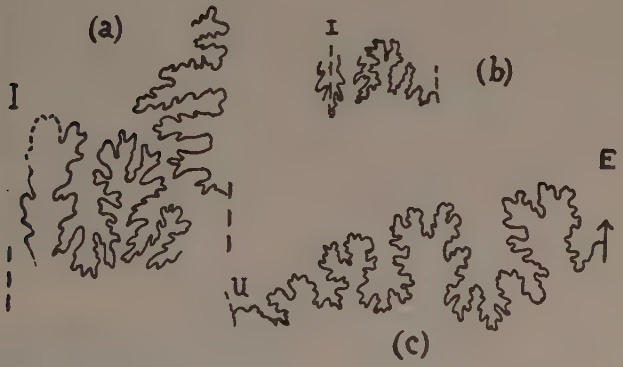

Fig. 2.—Suture-lines of *Pachydiscus sharpei* Spath. Natural size. (*a*) Internal suture-line (incomplete) of outer whorl, at a diameter of 180 mm. (*b*) ditto, diameter 65 mm. (*c*) complete external suture-line of outer whorl at a diameter of 80 mm.[1] E = external lobe; I = internal lobe; U = umbilical suture.

Observations.—This species differs from *Prionocyclus neptuni* (Geinitz) in its wider umbilicus, coarser costation, and less compressed whorl-shape, and from *Prionotropis carolinus* (d'Orbigny),[2] also in its more robust ribs and tubercles. *P. branneri* Anderson[3] is probably closely allied, but was described as having a long external lobe, and like *P. woollgari* (Mantell), has still coarser tuberculation. It is interesting to note that Anderson draws attention to the digitations of the suture being " not always regular, different septa of the same specimen showing considerable variation ". This irregularity can be seen in most of the Prionotropids, and as has recently again been pointed out by Dr. Spath,[1] in the highly ornamented stocks the suture-line is too variable to enable one to utilize its proportions for specific distinction.

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[1] The use of the symbols IS and IL in a recent paper in the Geological Magazine (1927, p. 76) for the first lateral saddle and first lateral lobe espectively, is confusing, since these symbols are almost universally accepted as denoting internal saddle and internal lobe, unfortunately neglected by many ecent writers. (See Zittel-Eastman, *Text-book of Palæontology*, fig. 1146, . 620, 2nd ed., 1913.)

[2] *Pal. Française Ter. Crét.*, i, 1842, pl. xci.

[3] "Cret. Deposits Pacific Coast": *Proc. Calif. Acad. Sci.*, 3rd series Geol.), vol. ii, No. 1, 1902, p. 125, pl. i, figs. 11–16.

A fragmentary example of the species here described, from Aston Rowant, Oxon, is in the British Museum (No. C. 14041).

Genus PRIONOCYCLUS Meek, 1876.

Prionocyclus hitchinensis sp. nov. (Pl. XVI, Figs. 1*a–f*, 2*a–b*.)

Specific Characters.—Coiling platy-, subleptogyral, subangustumbilicate. Whorl shape compressed, sides flattened. High median keel on a tabulate periphery. Umbilical wall perpendicular with abrupt edge. Costation, first single, later more irregular, with occasional bifurcation, and slightly thickened at umbilical edge; abrupt termination at peripheral shoulders but no definite tubercles; strongly projected forward throughout.

Suture-line simple, with bifid external and lateral saddles and two auxiliary lobes. Dorsal portion with three saddles. An additional fragmentary specimen (Fig. 2*a* in Plate) has a suture-line which differs chiefly in the details of the lateral saddle.

Measurements of Holotype.—21, ·50, ·26, ·19.

Observations.—*Prionocyclus hitchinensis* is more compressed and flattened than *P. neptuni* (Geinitz). The ribbing is less strongly developed and diminishes rapidly with growth of whorls. A portion (not here figured) of an outer whorl, 8 mm. in width, of the holotype showed only very faint ribbing. From this the internal and external suture-lines shown in Fig. 1*f* were obtained. The keel is almost continuous, not serrated like that of *P. neptuni*, and there are no outer tubercles on the latero-peripheral margin. Very young examples, however, are similar. *P. wyomingensis* Meek,[2] according to a well-preserved young example in the British Museum (No. C 26259) is similarly closely ribbed but more evolute, and does not lose its costation at such an early stage.

A small whorl fragment of *P. hitchinensis* was found in the interior of the large *Pachydiscus sharpei* described. The British Museum has a small example (No. 23156) of the present species from the Middle Chalk of Kent.

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[1] " Notes on Yorkshire Ammonites " : *The Naturalist*, 1926, p. 326.

[2] The type-fig. in White (1883, " Contrib. to Invert. Pal. No. 2 " : 12*th Ann. Rep. U.S. Geol. and Geogr. Surv. Territ.* [1878], p. 35, pl. xv, fig. 1*a*) is incomplete and the smaller paratype is obviously incorrectly drawn.

Family ANISOCERATIDAE Hyatt, 1900.

Genus Hyphantoceras Hyatt, 1900.

Hyphantoceras woodsi (Kitchin). (Pl. XVI, Figs. 5*a*–*b*, 6.)

1896. *Heteroceras* sp. Woods. Loc. cit., p. 75, pl. xi, figs. 6–8.
1922. *Heteroceras woodsi* Kitchin. *Mem. Geol. Surv.*, "The Geology of the country around Beaconsfield," Appendix, p. 49.

Dr. Kitchin first recognized this form as a distinct species. Two specimens are here figured. The earlier whorls are in contact, but the shell straightens out in the final stage as shown in Fig. 5*a*. The whorls are sub-elliptical in section, with a depressed upper area where the whorls are in contact (see 5*b*). The body chamber fragment (Fig. 6), consisting of two whorls, shows fine ribbing, with one prominent constriction, and a change in obliquity of ribbing, with more distant costation, towards the aperture. In Fig. 6 there is a smaller difference in diameter of adjacent whorls than shown on the figure of *Heteroceras* sp. by Mr. Woods, and the exterior bulge of the whorls is less pronounced. Several other specimens of *Hyphantoceras* have been secured, showing various degrees of straightening. It is interesting to note that a specimen of *H. woodsi* was found in the matrix filling the body chamber of the larger *Pachydiscus sharpei* already mentioned.

Family PHLYCTICRIOCERATIDAE Spath, 1926.

Genus Allocrioceras Spath, 1926.

Allocrioceras aff. *ellipticum* (non Mantell) Woods sp. (Pl. XVI, Figs. 4*a*–*c*, 7*a*–*b*.)

1896. *Crioceras ellipticum* (non Mantell) Woods. Loc. cit., p. 84, pl. iii, figs. 8–10.
1926. *Allocrioceras ellipticum* (Woods) Spath. Loc. cit., pp. 80–1.

The specimen figured (Figs. 4*a*–*c*) differs from those illustrated by Mr. Woods, notably in the arrangement of the ribs and tubercles, but until more complete specimens are found it is not advisable to introduce a new name. Ribs and tubercles in the present form are approximately equal in size, not varied as in the figure by Mr. Woods, and are less prominent on the inner (dorsal) area. Each rib bears two tubercles, terminating in sharp points, one on each side of the siphonal lobe. The larger specimen here figured shows the ribs and tubercles disposed radially, but the smaller example (Fig. 7) displays these arranged obliquely. Both are body chambers and are elliptical in section. This latter fragment probably belongs to a different species and may have to be given a separate name when better examples are available.

In conclusion, I have to acknowledge my great indebtedness to Dr. L. F. Spath for his untiring help freely given at various stages during the preparation of this paper. It was his constant advice and encouragement that enabled me to carry the work to the present stage. I wish also to record my thanks for the facilities afforded for the palaeontological work by the Geological Department at Birkbeck College, University of London.

EXPLANATION OF PLATE XVI.

All the specimens figured are from the Chalk Rock. All are of natural size except Figs. 1*c–f* and 2*b*.

FIG.

1.—*Prionocyclus hitchinensis* sp. nov., holotype (internal cast). Lateral (*a*) and peripheral (*b*) views; (*c*) ditto, twice natural size; (*d*) part of suture line showing external and lateral saddles. E = external lobe; U = umbilical suture; (*e*) umbilical portion of external suture line; (*f*) suture line of outer whorl (not figured) of holotype from internal lobe (I) to lateral saddle.

2.—*Prionocyclus hitchinensis* sp. nov., paratype. (*a*) lateral view; (*b*) external suture line.

3.—*Prionotropis cristatus* sp. nov. Lateral view (*a*) of holotype, with outline whorl-section (*b*) and last external suture-line (*c*); the outer half-whorl represents the body-chamber.

4.—*Allocrioceras* aff. *ellipticum* (Woods, *non* Mantell). Lateral (*a*) and peripheral (*b*) views, and (*c*) outline whorl-section of body-chamber fragment.

5.—*Hyphantoceras woodsi* (Kitchin). Basal view (*a*) and outline whorl-section (*b*) of body-chamber fragment, showing straightening out of final stage.

6.—*Hyphantoceras woodsi* (Kitchin). Lateral view of nearly complete body-chamber, showing distant costation near the aperture.

7.—*Allocrioceras* sp. ind. Lateral view (*a*) and outline whorl-section (*b*) of small fragment.

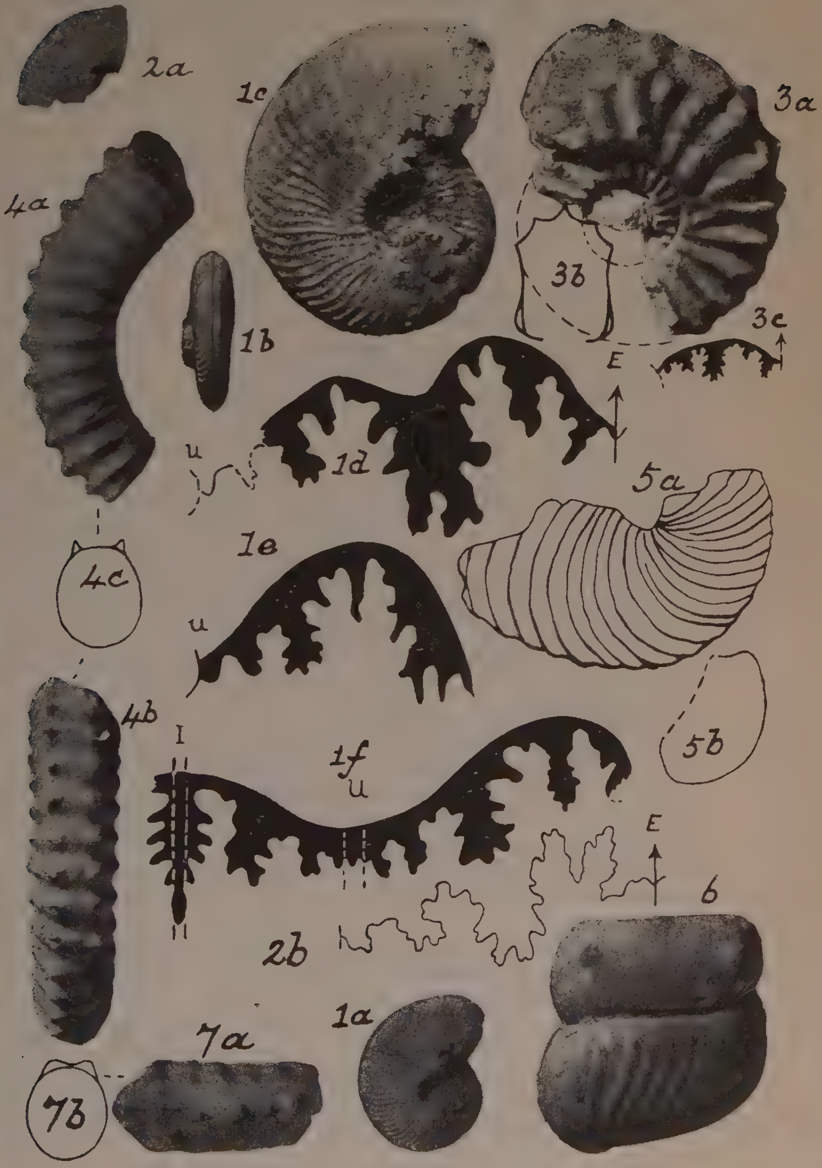
Mangaia and Rurutu: a Comparison between Two Pacific Islands.

By L. J. Chubb, M.Sc.

PROFESSOR PATRICK MARSHALL'S important and interesting memoir, which has recently appeared, on the geology of Mangaia, one of the Cook Islands,[1] inevitably suggests a comparison between this island and Rurutu in the Austral Group, which I visited in 1925, during the *St. George* Expedition to the Pacific, and described in a recent communication to the Geological Society.[2] Owing to the shortness of the Expedition's stay at this island, my observations were necessarily somewhat incomplete, but I had the advantage of many conversations with Mr. S. Russell, who spent several months there in 1924, prospecting for minerals. He gave me copies of his reports, and he accompanied us on our visit.

[1] P. Marshall, "Geology of Mangaia": *Bernice P. Bishop Museum Bulletin* 36, Honolulu, 1927.

[2] L. J. Chubb, "The Geology of the Austral or Tubuai Islands (Southern Pacific)": *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, pp. 291–316.



AMMONOIDEA FROM THE CHALK ROCK.

Rurutu and Mangaia are separated by a distance of less than 400 nautical miles, and they lie within half a degree of the same latitude (respectively 22° 27′ S. and 21° 54′ S.). Both are primarily volcanic islands, bearing plains of marine erosion now elevated to heights of several hundred feet above sea-level. On both the volcanic rocks are very considerably decomposed to red lateritic clay, and the surface topography of both is somewhat subdued, being without prominent peaks and razor-backed spurs. Around both there are elevated coral-reefs, the upper surfaces of which now stand between 200 and 300 feet above sea-level, and which face the sea in lines of nearly vertical cliffs. Finally, both are surrounded by fringing reefs at sea-level.

There is obviously a close similarity between the two islands, but there are various differences of greater or less importance. At Mangaia the Central Plateau, an old surface of marine erosion, now standing 554 feet above sea-level, forms the summit of the island (p. 7).[1] At Rurutu the similarly formed 800 feet plateau is over-shadowed by Manureva Peak, which rises to an altitude of 1,300 feet. Evidently Mangaia was completely truncated by marine action prior to elevation (p. 39), while Rurutu was reduced to a small island surrounded by a broad submerged platform. At Mangaia Professor Marshall found the volcanic rocks deeply decomposed over the whole surface of the island, and he was able to collect very few specimens fresh enough for determination (p. 36). There was no such difficulty at Rurutu, where, up to an altitude of 200 feet, the rocks are very little altered. Between 200 and 600 feet they are generally considerably decomposed, but there is no difficulty in collecting fresh samples, chiefly from the unaltered cores of spheroids. It is only above this altitude that the rocks have been completely weathered to clay. It is suggested that this may be due to a second stationary period, when the island stood 600 feet lower than it does now, and its emergent portions were subjected to intense subaërial alteration. Truncation by marine action may have been prevented by some slight development of coral reefs, which have been almost destroyed by subaërial erosion since elevation occurred, though Mr. Russell informs me that he has found small outliers of limestone up to altitudes of perhaps 500 feet. None such occur on Mangaia (p. 37).

On Mangaia again there has been no volcanic activity since the formation of the elevated reef (the "Makatea") began (p. 45). In Rurutu, on the other hand, there are considerable deposits of palagonite-tuff on the surface of the raised limestone terrace in the southern part of the island.

Professor Marshall did not find any exposure of the junction between the Makatea and the underlying volcanic rock at Mangaia (p. 22). Such exposures occur at Rurutu on the shore at the base of the limestone cliffs. They prove that the elevated reef at its outer edge is not much more than 200 feet thick. Professor Marshall estimates the thickness of the limestone rock at the outer edge of the Makatea at Mangaia at approximately 1,000 feet (p. 46). He found no fragments of volcanic rock included in the limestone (p. 23), but at Rurutu such fragments are common in the lower parts of the elevated reef, and at Matoatahi Point, on the west coast, there is a basal conglomerate 20 feet thick, consisting of pebbles of volcanic rock in a calcareous matrix, resting unconformably on lava, and dipping at about 20° towards the sea. It was not found possible to determine whether the erosion that had been suffered by the subjacent surface was due to subaërial or to marine agents.

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[1] The page references are to Professor Marshall's paper.

A still more striking difference between the two islands is to be found in the relationship of the elevated reefs to the volcanic slopes. At Mangaia the central volcanic hill is separated from the Makatea by a moat-like depression (p. 35). The floor of this, the "Taro Flats", is level and swampy, generally not more than a quarter of a mile wide, and elevated about 40 feet above sea-level. It completely encircles the central hill, though at four points low spurs from the latter extend across it to the Makatea. The latter faces it in a line of towering cliffs, 150 feet or more in height. The Taro Flats are drained by subterranean channels passing to the sea through the Makatea at depths of more than 150 feet (p. 7).

No depression corresponding to the Taro Flats was seen along the north-eastern or western sides of Rurutu, the only parts visited. The terrace on the summit of the elevated reef is continued inland until it reaches the volcanic slopes. In these districts too the drainage does not make its way to the sea underground. The streams have cut valleys, which in some cases are quite broad, through the elevated reef, and flow from their source to sea-level over volcanic rock. I find myself, therefore, unable to agree with Professor Marshall's opinion that the action of rain and small streams can have but little effect on raised coral rock (p. 44).

Most of the differences so far enumerated between the elevated reefs on the two islands can possibly be explained by assuming that that around Rurutu was formed as a fringing-reef during a stationary period, a prolonged pause in the general movement of elevation, and that the Makatea at Mangaia grew, as Professor Marshall believes, as a barrier-reef, separated by a lagoon from the central volcanic island, and, assuming his estimate of the thickness of the limestone to be approximately correct, it was formed during a period of very considerable subsidence, though he attributes part of this thickness to outward growth of the reef on a talus of coral-fragments during elevation.

Although in the parts of Rurutu visited by me there is no depression behind the elevated reef, Mr. Russell informed me that there is one, the Paparai Valley, in the south-eastern part of the island. The volcanic slopes descending into this valley are densely covered with a jungle of "maniota",[1] and apparently the uplifted reef faces it in a line of steep cliffs. The valley bottom is swampy and contains pools of water, but I have no information about its flatness, or its elevation above sea-level. The drainage makes its way to the sea through caves cut in the base of the limestone.

Evidently the Paparai Valley has many features in common with the Taro Flats of Mangaia, but various considerations make it seem probable that it should be regarded as a subaërial-erosion feature, and not as a lagoon-moat.

In the first place it seems unlikely that there should be such a well-developed lagoon behind the reef for a distance of a mile or two along the shore, and no trace of a similar feature round the rest of the island. A more cogent argument is derived from the occurrence of pyrolusite in superficial pockets in the volcanic rocks on the slopes of the valley. This mineral has been found at many localities around the island, but in every other case it occurs in pockets at the junction of the reef-limestone, which in these districts is impregnated with dendritic manganese, with the underlying volcanic rock. The conclusion seems inevitable that, in the conditions prevalent on the island, the presence of an overlying stratum of manganiferous limestone is necessary to bring about the concentration of the mineral. It seems probable, therefore, that the elevated reef was formerly continued inwards and rested on the slopes of volcanic rock, and that the disappearance of this inner portion, with the formation of the Paparai Valley, is due to recent subaërial erosion.

The process by which this might be brought about is not difficult to follow. The streams descending the slopes round the other parts of the island failed to find fissures through the elevated reef, and accordingly flowed over it, cutting valleys in it, which they deepened until finally they ran directly on volcanic rocks. The valleys were then widened by subaërial agents till at last considerable stretches of the reef were destroyed. In the Paparai district, however, the elevated reef was for some reason more permeable. It may possibly have been composed in part of different organisms, in consequence of the prevailing wind having been in this quarter during its formation. The drainage was able to make its way to the sea through fissures in the limestone, which were gradually enlarged into caves. The valleys in the volcanic slopes above the elevated reef were widened by ordinary subaërial agencies. Subsequent tributary streams flowed along the line of junction of the volcanic rocks and the reef-terrace, undermining the feather-edge of the latter, and causing it to retreat. The process thereafter was similar to that leading to the development of escarpments in regions of dipping strata, as described in every textbook.

I venture to suggest that this process may have taken a part, perhaps only a small one, in the shaping of the depression containing the Taro Flats at Mangaia. It would help to account for the variations in width of the Makatea. It would explain the uniformity in depth of the moat, as the streams would attain base-level a few feet above the level of the sea. Otherwise this uniformity is a little difficult to understand, as it is a feature shown by very few existing barrier-reef lagoons, in which the depth usually varies between 10 fathoms and 30 fathoms in different parts of the same lagoon.

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[1] Mr. L. A. M. Riley, of Kew Herbarium, informs me that this is probably *Manihot utilissima* Pohl, or possibly *M. aipi* Pohl.

Professor Marshall's discovery of *Lepidocyclina* (p. 26) proves that coral-growth started at Mangaia in the middle Tertiary, and he considers that the Makatea emerged above sea-level in the upper Miocene (p. 44). There would thus appear to have been ample time for a considerable amount of subaërial erosion to have taken place.

A Conglomerate in the Nummulitic Formation of Gebel Moqattam, near Cairo.

By J. Cuvillier.

IN 1924 I drew attention[1] to the presence of a coarse-grained conglomerate at the base of the Gebel Moqattam, near Kait Bey. This paper contains a detailed description of the occurrence, of which at the same time I shall endeavour to determine the stratigraphical significance.

The actual section consists of alternating bands of sandstones and conglomerates, each type of rock being represented by three of these; while the lowest of the beds consists of sandstone. The uppermost conglomerate is directly overlain by nummulitic limestones of Lutetian age, with *Velates schmiedelii* Chem., *Serpula crassa*, *Natica cepacaea*, Lmk., *Vulsella deperdita* Lmk., *Macrosolen uniradiatus* Bell., etc. The total thickness of this series of sandstones and conglomerates (*poudingues*) attains 2·50 metres, and the part which is visible forms the axis of a slight anticlinal undulation, trending in a north-south direction.

The conglomerates are mainly formed of calcareous and crystalline, rarely of siliceous, constituents, and some clayey nodules are mixed with them. In these I have collected fragments of silicified wood.

The sandstone is very coarse-grained, brownish in colour, loosely bound together by an argilo-calcareous cement, and it appears to have been deposited in shallow water, perhaps close to a shoreline or near the mouth of a river. Fossils are rare in the conglomerates and in the sandstone, nevertheless there are some Ostreae and spines of sea-urchins, which indicate a *marine* formation. The study of thin sections of some flakes of the sandstone has enabled me to recognize some badly-preserved *Nummulites* and fragments

[1] J. Cuvillier, "Contribution à l'Étude Géologique du Moqattam": *Bull. Inst. Egypte*, 1923–4.

of Operculinae. The presence of beds of essentially detrital character at the base of the thick series of nummulitic beds developed in the Gebel Moqattam presents a most interesting problem. The nummulites present in the sandstone come from a lower level which is evidently not Cretaceous. It remains therefore to determine whether they belong to the Lower Eocene or already belong to the Middle Eocene series.

The occurrence at several localities in Sinai of conglomerates, intercalated in the Meso-Nummulitic beds strengthens the second hypothesis.[1] The difference of levels cannot in any case be very great between the beds of the lowest Lutetian and those of the Upper Libyan.

It is certain that we have here to deal with deposits formed during an oscillation, or more strictly speaking a series of oscillations of short duration during which the Nummulitic sea had its shoreline near Cairo. This must have occurred at some period during its retreat northward ; a period of arrest of the withdrawal permitted the formation of the detrital beds, grits and sandstones alternating, indicating slight displacements of the shore line. Then, all the evidence tends to indicate that the waters of the sea once more invaded the areas which they had abandoned, to deposit the Lutetian sediments (limestones with *Nummulites, Gizehensis*, etc.), as far as the neighbourhood of Minia. After this event, a last oscillation of great significance caused the Nummulitic sea to retreat to the north, causing the deposition of the beds which we group under the name of the Upper Moqattam.

It may be that this hypothesis will be confirmed by the discovery in the Valley of the Nile of a conglomerate analogous to that of Kait Bey. This would open up new horizons in the study of the stratigraphy of the Nummulitic formations in Egypt.

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[1] F. W. Moon and H. Sadek, " Preliminary Geological Report on the Wadi Gharandel Area, Egypt " : *Petr. Res. Bull.*, No. 12, Ministry of Finance, Cairo, 1922, p. 29 ; also " Preliminary Geological Report on Gebel Khoshera area (Western Sinai), Egypt " : *Petr. Res. Bull.*, No. 9, Ministry of Finance, Cairo, 1925, p. 23.

REVIEWS.

THE CAMBRIAN, OZARKIAN, AND CANADIAN FAUNAS OF NORTH-WEST GREENLAND. By CHR. POULSEN, Meddelelser om Grønland, vol. lxx. Jubilaeumsekspeditionen Nord om Grønland, 1920–23, Nr. 2, pp. 237–343, 10 t.f., 8 pl. København, 1927.

THIS important memoir is written in English and deals with fossils collected by the Danish explorer and geologist Lauge Koch during the 1916–18 and 1920–23 expeditions to North-west Greenland.

A locality map is given, and the strata are briefly described : the latter range from Lower Cambrian to Upper Canadian ; the Upper Canadian are unconformable with the underlying Upper Ozarkian. This description is followed by palaeontological notes (stratigraphically arranged) covering over 100 species of algae, graptolita, mollusca, brachiopoda, trilobita, and ostracoda, but, of all these, only four forms are identified with existing species. In addition, the author provides good phototype illustrations and a systematic study of trilobite classification, and the memoir concludes with correlative remarks on the faunas.

The lowest Cambrian Formation yields an essentially North Atlantic *Callavia* fauna, whilst the two succeeding Cambrian deposits (Lower and Middle) show connexion between Greenland and the Cordilleran Sea ; but even in those times the Arctic Basin was partly isolated, as is evidenced by the many new Greenland species and some new genera, and further by the absence of such widespread families as the Agnostidae, etc.

The Greenland Upper Ozarkian is closely related to that of the Missouri and Arkansas region, but we note in the fauna the genus *Eoorthis*, frequently found in the European Tremadocian, and also a near relative of Callaway's genus *Macrocystella* in " Cystoidea, Gen. et sp. indet. p. 282, pl. xvii, figs. 37–40."

The Upper Canadian Beds yield *Didymograptus bifidus* and *Phyllogr. angustifolius*, but the bulk of the fauna is of a more restricted North American type.

The section on trilobite classification formulates a scheme which is virtually a critical selection from those of Beecher, Swinnerton, and Warburg, with certain new independent views, and it seems worthy of high consideration.

The author, like Warburg, considers the Mesonacidae to be the most primitive trilobites and he raises the family to the status of an Order, removing it from the Opisthoparia.

The Order Mesonacida is considered to originate two off-shoot Orders (which have been given unfortunately cacophonous hybrid names), the Integricephalida in which facial sutures are as yet undeveloped, and the Suturicephalida where facial sutures are present; this last group comprises two sub-Orders, the Proparia and the Opisthoparia.

Although, in the Mesonacida, cephalic-ecdysis is stated to initiate in a " marginal suture " which separated the rostrum from the rest of the cephalon, an exact counterpart of a true (Opisthoparian) facial suture " *in statu nascendi* " is claimed by the author to have existed and to have functioned in certain members of this Order[1]; that is, he considers the true trilobite facial suture to have developed in this Order.

The marginal suture is regarded as homologous with that of the Hypoparia (Beecher). The Conocoryphidae are, it seems, somewhat arbitrarily considered to possess a marginal and not a facial suture and, together with the Hypoparia but excluding the Raphiophoridae, constitute the Order Integricephalida. This Order evolved from the Mesonacida before the complete facial suture was developed, but the posterior branch of the facial suture is thought by the author, Warburg, and others to be the definite posterior margin of the ocular segment and, *ipso facto*, mysteriously escaped elimination in the general cephalization of trilobites. This line of weakness would presumably be present in the earliest trilobites but has secondarily disappeared in the Integricephalida alone.

The inter-relationships of the component families of the Suturicephalida are discussed, and, in many cases, new conclusions are put forward.

We observe that with Walcott, Reed, and Warburg the author believes that Proparia and Opisthoparia only differ essentially in that the cheek-spine in the Proparia represents the " inter-genal spine " of the Mesonacida, but in the Opisthoparia it represents the " genal spine ". Dr. Poulsen considers the common ancestor of the Pro- and Opistho-paria to be related to the Mesonacida and to have had both genal and inter-genal spines; subsequent development led to suppression of one or other of these spines. The early larval stages of certain Mesonacida reveal a condition where the cheek spine is inter-genal and, according to Walcott and others, in most Mesonacids the adult cheek-spine is genal. The author states that in the developmental histories of some Opisthoparian trilobites early Proparian stages occur; and concludes that this fact indicates not necessarily the evolution of the Opisthoparia from the Proparia, but rather the recapitulation of conditions which determined the character of the ancestor of the Mesonacida.

We regret that consideration has not been given to Raw's 1925 *Q.J.G.S.* paper, particularly to that writer's case for the importance of the " Pro-cranidial spine " in Trilobite evolution.

An ideal classification of the trilobites has yet to be constructed, but Dr. Poulsen's study should be read with attention and merits our gratitude.

C. J. S.

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[1] These views were first tentatively suggested by Raymond, *Am. Journ. Sci.*, 1917, p. 208.

PLANTS OF THE PAST. By F. H. KNOWLTON. pp. 273 + xix, 90 figs. 1927: Princeton University Press (Humphrey Milford, London). 16*s*. net.

THE late Dr. Knowlton made a long series of contributions to our knowledge of the fossil plants of North America, and his last work was an attempt to give an account of the salient facts about the plants which clothed the earth in former times. It is not intended to be a text-book but rather a narrative for the general reader, and it is well illustrated by photographs of specimens as well as by restorations. The plan of the book is good, it includes chapters on the preservation of plants, coal, the problem of organic evolution, the influence of plant life on animal evolution, and on the value of the study of fossil plants. Parts of the work are very well done and make interesting reading, while the chapters dealing with the Cretaceous and Tertiary times are valuable summaries of the state of knowledge with special reference to North America.

In a book of this type, which covers a large field, it is perhaps inevitable that some points should be open to criticism, and from the botanical side a considerable number of criticisms may be fairly made. From a geological standpoint the work loses value owing to the obscuration or neglect of an important principle in dealing with fossil floras throughout the ages. This is the recognition that the accepted units of geological time are generally based on marine sediments and marine organisms, while most plants are terrestrial organisms, consequently the floristic periods in the earth's history cut across the sedimentation periods. Thus the Upper Devonian floras cannot be separated from the Lower Carboniferous floras, but there is an important break between the Upper and Lower Carboniferous vegetation. The neglect of this principle is especially noticeable in the chapter on the Devonian floras, where an entirely erroneous impression is given.

Finally we must mention with regret that some of the recent palaeobotanical "mare's nests" have been perpetuated, such as the description of a *Medullosa* petiole from the Carboniferous of Illinois as an Angiosperm stem.

H. H. T.

CORRESPONDENCE.

CLIMATIC CORRELATION OF RAISED BEACHES.

SIR,—The paper by Mr. D. Baden-Powell in your October issue dealing with the present climatic equivalents of the raised beach faunas contains some interesting data and employs a method of research which has been most effectively used in the past and is no doubt capable of further extension. One cannot but hope that Mr. Baden-Powell will go on with it, and apply his knowledge of the mollusca to further climatic determinations of a similar nature.

At the same time it is essential to realize that the use of this climatic factor in the correlation of one beach with another is liable to very serious error, and has indeed in the author's hands already led to conclusions which are unquestionably erroneous. His work has, I fear, the common defect of much palaeontological research of having an insufficient background of field work. I have even grave doubts as to whether he has covered the literature of his subject. If he had he could hardly have been led into the error of correlating the pre-glacial raised beach of Gower in South Wales with the post-glacial raised beach of Scotland. The former is earlier than any boulder-clay observable in contact with it in South Wales or Ireland, the latter is later than any boulder-clay or moraine occurring in the whole area of its distribution in Scotland. How is it possible that the boulder-clays laid down at the maximum extension of the ice in Wales and Ireland could be later than the local moraines of Scotland? It is clearly not possible, and therefore the author's correlation must be wrong. The post-glacial, so-called 25 foot beach is moreover not always at a height of 25 ft. above O.D., but ranges in height from 35 ft. above high water mark at the centre of its area of distribution down to sea-level at the periphery. It becomes coincident with or descends below sea-level far north of Gower and is not found as a raised beach in South Wales. Its fauna as exhaustively studied by Dr. Praeger in Northern Ireland is noticeably warmer than that of the present shore, so that it will indeed be a remarkable and interesting fact if it should be colder in Scotland. This is not at all so impossible as might appear at first sight, for, as I have pointed out elsewhere, there is archaeological evidence indicating that the post-glacial beach may have quite different dates of origin at its periphery and its centre. I feel therefore that the author's line of work may be of enormous importance in this respect, since the building of the beach may possibly be prior to the climatic optimum in the central area and later than it in the peripheral area. All that we know at present is that it is contemporaneous with it in the intermediate area of Northern Ireland.

Now if I understand the author aright he does claim to have proved the fauna of the 25 ft. beach of Scotland to be colder than that of the present day. If so he has put a nail in the coffin of his method of correlation by temperature, but he may nevertheless be arriving at a result of the utmost importance. I can only beg him to persevere, but to look upon his faunal methods as a means of proving that beaches are not contemporaneous, rather than that they are.

I might perhaps make one or two further points to avoid misunderstanding. The author states that no obvious warping appears to have occurred since 100 ft. times, the level of the 100 ft. beach remaining constant throughout Scotland according to the measurements of the Survey. The fact is that these measurements are neither accurate enough, nor distributed widely enough, to establish any such conclusion. This beach has been excluded or destroyed by a glaciation throughout the whole central area. It is known over a relatively narrow belt round about this blank area and its height is not altogether constant even here. Further out it is unknown and nobody has yet been able to offer a reasonable suggestion as to what becomes of it. The belt along which it is known may correspond roughly with the 100 ft. isobase of deformation. Moreover it is patently absurd to say it has suffered no warping, since the later 25 ft. beach is so obviously warped throughout the area occupied by the 100 ft.

The author makes an amazing use of Mr. Hinxman's valuable observations at the head of Loch Torridon. He cites them on p. 406 as proving a readvance of the ice between 50 ft. and 25 ft. times and later, on p. 437, as suggesting an advance subsequent to 25 ft. times. Now Mr. Hinxman only mentions one readvance, and it cannot well do double service as being both pre- and post- 25 ft. An explanation of what is meant would be very welcome in this instance.

Finally, I should like to ask the author if he has guarded against a source of error liable to be introduced by working over old collections of raised beach shells. There is always the possibility that a certain proportion of kitchen-midden material may be included in these, as the early collectors were not always careful to discriminate, and regarded any shells found above sea-level as an indication of change of level.

W. B. WRIGHT.

MANCHESTER.
10th October, 1927.

ERRATUM.

In Fig. 2, p. 68 (February, 1927), the base-line of the section should be horizontal, the stratification-plane dipping to the right.